ENGINEERING

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Survey by Professor O. A. Saunders

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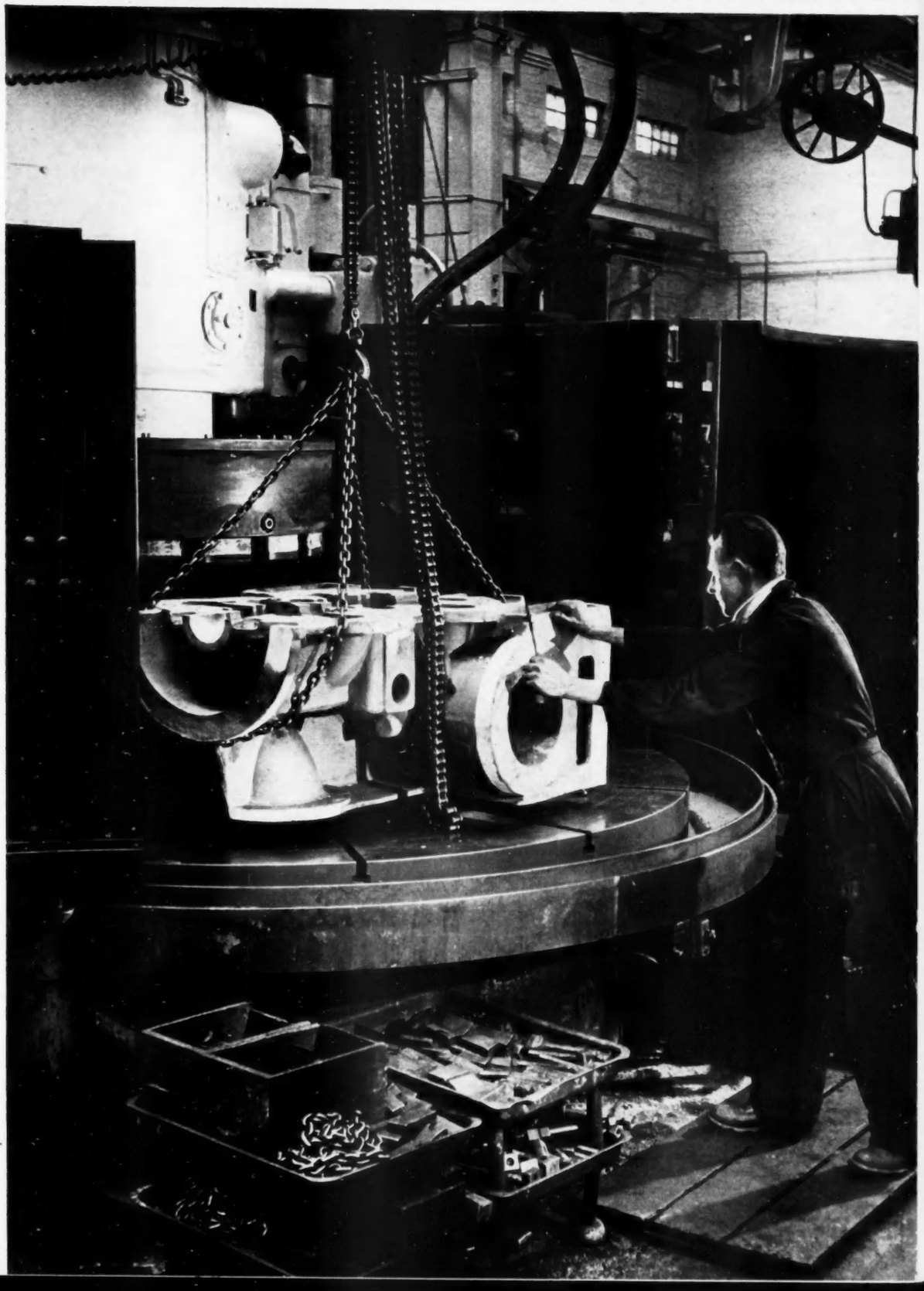

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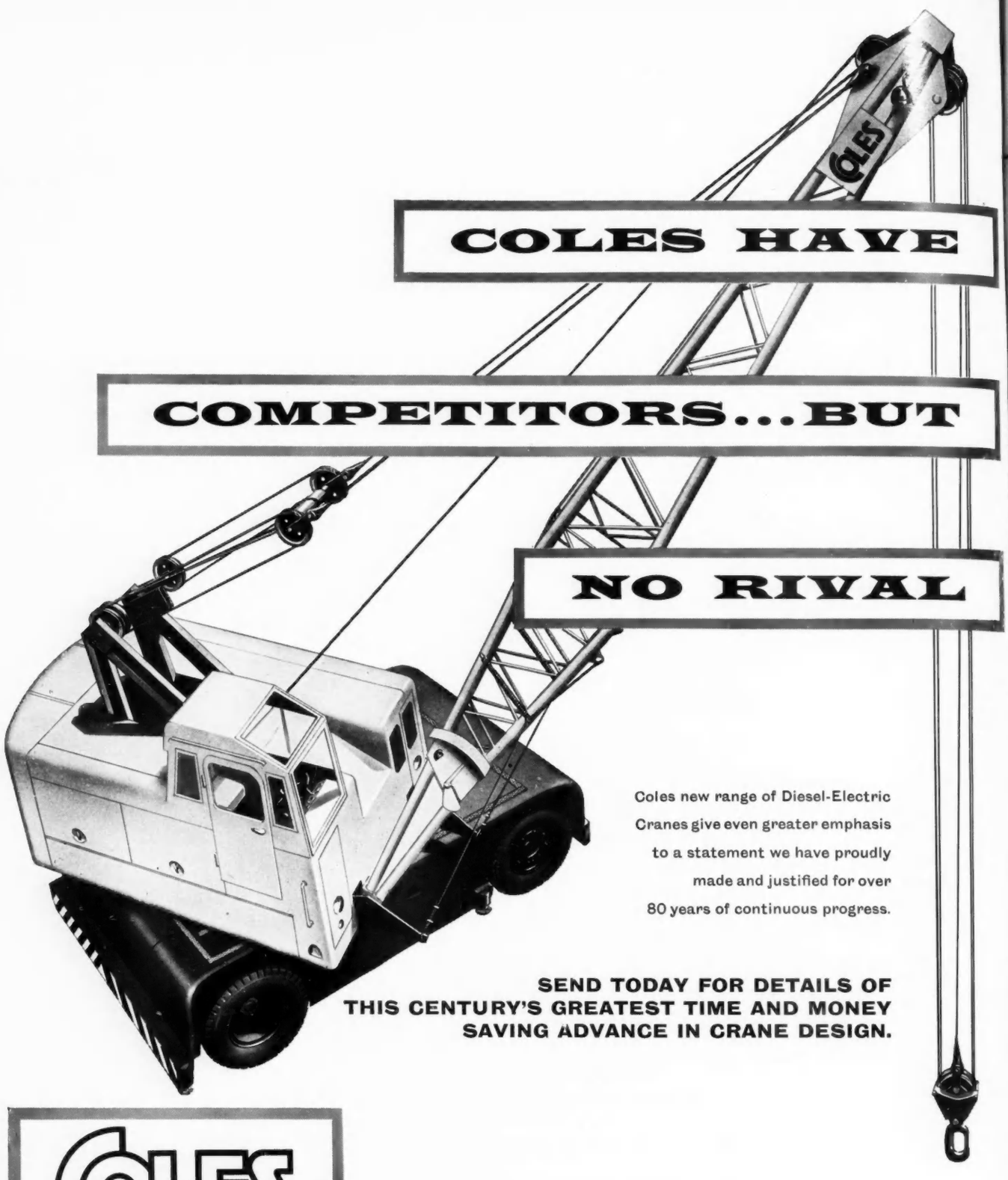

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Eye of a Stranger

THE river is not a broad one, and it seldom bursts its banks. On each side there is thick unchecked vegetation. Trees overhang the river's edge, dipping their trailing branches in its waters. The land has a natural fruitfulness, but there are no signs of people, or of habitation. It is a country populated only by rabbits and field mice, by murmuring insects, by foxes and the momentary trespassing of butterflies. No men have penetrated to its interior; no house was ever built there; no field was ever ploughed. Then, above the preoccupation of the river, the lapping of its water, the whispering of its creatures, is heard the faint chugging of a man-made sound. A motor launch creeps into view. Standing on deck are two men; they wear light-brown shifts of a fine but tough material, and their skins are black. One, tall with spectacles, carries a geologist's hammer; the other, thickset and restless, is an engineer. The tall one points to where concentric ripples show the sudden rise of a fish. And in a moment the first ripples are augmented by many more as rain begins to fall. The geologist dashes below, but the engineer shivers and seizes an oilskin, pulling it over his head. The country is England, and the river is the Thames.

Imagine a party of prospectors arriving in Britain to find it uninhabited. What would they report? Would they write it off as a pleasant place for a holiday or as good pasture land, and little more? Or would they find it rich and promising? In his William Menelaus Memorial Lecture, delivered before the South Wales Institute of Engineers on the occasion of its centenary, Sir Charles Goodeve has proposed just such a study. At least that is the first part. Suppose, he says, that our island has been depopulated, and that a committee has been sent here to investigate its physical and geographical potentialities under five main headings: soil and climate, mineral resources including energy, access to the sea, internal communications, and geographical location. The second part of the exercise involves putting all the people back and assessing to what extent they have exploited and benefited from the island's advantages. One of the questions he seeks to answer is: "Should any one of us advise our children to emigrate to other parts of the Commonwealth or should we advise them to stay here?"

Sir Charles Goodeve has listed some of our most important assets. No factory can be located further than 90 miles from a port, through which it has access to the world's resources in raw materials. In fact for an area less than one-thirtieth that of the United States and one-hundredth that of the Soviet Union, we have 252 ports, a figure which these countries scarcely exceed. Britain has within its coastline a range of geological formations usually found spread over an entire continent, so that many different minerals can be readily assembled for industrial use. This accumulation together with the shape and size of the country should also simplify internal communications. Though our weather may be terrible, our climate is superb, providing more than adequate supplies of water; and our soil could support a population of 40 million people, even if we had no other assets.

The United Kingdom lies effectively at the centre of the land areas of the globe, so that it could conceivably form the ideal commercial and financial centre, and the most convenient repository for scientific and technical information. This advantage has been enhanced by the advent of air travel, for we are now within non-stop flying distance of capital cities representing over 90 per cent of the world's population. Sea and land travel have in the past brought us to think of the world as a cylinder; air travel has made us see it as a sphere, with Tokyo not east of London, but N32°E. Ideally, Britain's position might be a few hundred miles south-westwards, but no further.

The uneven way in which we have exploited these advantages has long been apparent. The time has come, perhaps, consciously to adapt our lives in accordance with our assets. Secretly many shrug their shoulders feeling that our days are inevitably numbered: eventually those countries that have vast territorial and human resources must necessarily acquire the technical skill by which at present we manage to maintain our position. Skill can only be an ephemeral advantage. Although this may be true, we have other blessings. The world is passing from a prodigal era when resources were sucked extravagantly from enormous areas and squandered indiscriminately, to a time when resources must be carefully husbanded. Perhaps in such a world, Britain, close knit and manageable, like a Commando unit, will have an unparalleled advantage.

If we look at our land with the appraising eye of a stranger we may better see its potentialities. Consider again the leader of an exploratory expedition preparing his report on an unoccupied Britain for his office in Accra. "We have," he writes, "come upon a country richly endowed, lying at the junction of the world."

Cover Picture.—*Within two hours of positioning this casting on the* 100 *in diameter table it will be rough ground and finished to size. The segmental wheel is driven by a* 100 *h.p. motor permitting a high rate of removal.*

(*Nurnberg photograph for* ENGINEERING)

* * *

Plain Words

Putting over a new idea is far easier than pushing through an old one that missed the boat before. People have a natural reluctance to hear a second time the arguments they know already, and come back well equipped with counter points. I would rather try to persuade London Transport to run triple-decker buses than suggest they adopt the well tried Continental practice of issuing tickets to passengers as they enter. Conservative resistance is reinforced by the contention that " if there had been anything in it, we should have taken it up before." Last week two important suggestions surfaced for the second time: paying wages by cheque and paying everybody monthly.

Personally I'm all in favour. Situations change, as does the mood of the country, and what was once rejected may now prove more acceptable. There should be a board to review discarded ideas and determine whether the circumstances are any more auspicious than they were. Sir Miles Thomas has taken up the case for payment by cheque. " We who run businesses," he writes, " are always looking for ways to reduce overhead charges, to improve security and to generate a sense of co-operation between workers and the firms that employ them. Handling and counting money in the form of notes and coin of the realm is a very costly process." He also quotes the argument that payment by cheque would serve to defeat thefts of wages in transit between bank and factory.

The snag, I gather, is the Truck Act passed " to prohibit the Payment, in certain Trades, of Wages in Goods, or otherwise than in Coin of the Realm. [15th *October*, 1831.] " No one is to be paid in kind, and cheques, it seems, are kind. Monthly payments are apparently immune. An electronics firm has recently considered weekly payments by cheque but, not wishing to fight it out in court, decided to withdraw. Mind you, some authorities feel that nowadays cheques could be treated as legal tender, so all that is needed is a test case and the whole thing would be settled.

The benefits are obvious. But the problems are also formidable, certainly in the case of changing over to monthly payments. But anyone who can complete a football permutation and budget for hire purchase should be capable of managing a bank account. With the advent of universal education, everyone has the right to grow up, and payment by cheque would encourage thrift and stimulate saving and investment. Look at me; I get paid by monthly cheque, but I don't blue it all in the first week; my wife sees to that. And what's so different about the chaps in the factory? They have wives, don't they?

CAPRICORN

Weekly Survey

Business or Pleasure Flight?

It has frequently been doubted whether the British aircraft industry could continue to maintain an annual display and exhibition on the scale of Farnborough. Such junketings in the grand manner tend inevitably to grow, with an implicit risk of getting out of hand. Apart from the direct cost of the Show itself, test programmes may be interrupted and the desire to bring the buyers and public something interesting each autumn almost certainly does impose a frenzy of activity on management and technical and production staff alike. Moreover, as the gestation period for radically new types grows inevitably longer, and we are all more and more completely inoculated against the shock of the spectacular, the superficial general interest in an annual display might perhaps have been expected to wane.

However, the display continues to attract and excite. A record number of overseas visitors welcomed and an estimated 238,000 of the British public, belied any suggestion of flagging general interest. While dramatic flying draws the crowds, it must not be forgotten that this is not the main purpose. It is difficult to dramatise a flypast of a turboprop airliner, or even the high speed of a jet airliner, but on such types, performing with difficulty in a limited air space, the future of the industry to a large extent depends. Nor is such demonstration likely to influence buyers to any measurable extent. An obvious exception to this is the field of vertical take-off. Here, even more pointed by contrast with conventional modes of flight, a demonstration such as that of the Fairey Rotodyne can be convincing in the extreme. A Rotodyne has recently been ordered by a major Canadian operator.

The sight of high speed at low level has become customary. More convincing is the maintenance of high speed over a distance, and the attendance of an Avro Vulcan at displays on both sides of the Atlantic in one afternoon was a dramatic demonstration of the aircraft's cruising speed.

It is, however, not only in the development of the radically new that success in the air depends. Steady subsequent development of successful types plays an equally important part. Such undramatic announcements as that the maximum take-off weight of the Viscount 810 series has been raised from 69,000 lb to 72,500 lb represent really significant advances (in this case an increase of range with maximum payload of 50 per cent) which add up over the years to a very considerable development—almost unnoticed by the superficial observer.

Farnborough is likely to continue. For proof the Society of British Aircraft Constructors state that sufficient new types of aircraft will be available to provide full and impressive displays during the next three years. And though the shape of things to come, in the more distant future, such as the Bristol proposal announced early in the month for a 2,000 m.p.h. turbojet and ramjet airliner, is to some extent known in advance, Farnborough—and the attraction of seeing such ideas translated into hardware in action—will continue to be a yearly congregation of the important men in aviation from all parts of the world. And serious business is conducted there as well.

Comparing Company Performance

For a long time those interested in good management have sought to interest companies in what are called in the jargon " interfirm comparisons." The idea is statistically a simple one although it has many complications in its application. It consists basically in the compilation of standard performance data by a group of concerns in an industry, each of which supplied the data on a confidential basis to some central organisation such as a trade confederation. The average performance is then published but not the individual returns, which are kept confidential. Each company taking part, and also those who did not, can then compare its performance against the average in the industry.

This idea has been applied fairly extensively in the United States and in Western Germany, but its progress in this country has been somewhat slow due mainly to the tradition of secrecy in British industry. The British Institute of Management has now produced a pamphlet in its Management Economic Series called *Interfirm Comparison for Management* (price 17*s* 6*d*). This sets out the basic idea of interfirm comparisons and gives six examples of how the technique can be used. Five out of the six examples are taken from the engineering and metal-forming industries. A third section is then given dealing with how to start interfirm comparisons in an industry and answering certain criticisms which management may have about the idea. Finally a series of appendices gives a classified list of industries in different countries where interfirm comparisons have been introduced.

The idea merits a much more sympathetic attitude on the part of the industry in this country than it has had so far. Most, probably all, the information required is already available in companies' accounts, cost sheets and stock lists. In an age when this country is going to have to compete increasingly with western European industry it is important that each concern should know how it compares with the average in the industry at home and with the average in the industry in other countries.

Reserves for Trade

While the shortage of liquid funds in financing international trade is by no means the only factor limiting economic activity in the free world, it is one which has been receiving increasing attention over the past year. In particular, the fall in commodity prices since the beginning of the year has focused attention on the plight of the primary producing countries whose dwindling receipts must sooner or later be reflected in a markedly reduced ability to purchase manufactured goods from the industrialised countries. The United States proposals for a general increase in the quotas of the member governments of the International Monetary Fund, which will be discussed at New Delhi in October, are accordingly of great importance in assessing the future outlook for exports of manufactured products including those of the engineering industry.

Quite apart from special factors, such as the fall in commodity prices, there has been a general decline in the amount of finance available in relation to the volume of world trade. It has recently been pointed out that before the war, in 1938, the world's monetary reserves (excluding those of the United States) amounted to nearly 42 per cent of the world's trade turnover, but that by 1957 this had fallen to 25 per cent. The extreme example of lack of liquidity has been provided by the sterling area, which holds only about 4 per cent of the world's monetary reserves, in spite of some 40 per cent of world trade being settled in sterling currency. This shortage of reserves has meant that many countries have had to impose restrictions on imports, or to reduce the level of their economic activity, much more quickly than would have been necessary if they had possessed adequate reserves or could have drawn upon an international fund to tide them over temporary difficulties. The effect tends, of course, to be cumulative, since the restriction of imports into Australia, for example, from the United Kingdom

may compel the latter to reduce imports from other countries.

Germany has already announced her willingness to increase her quota with the IMF from 330 million dol to 500 million dol, provided other countries make proportionate increases, and the United States proposals mentioned above are to a large extent based on suggestions made by Mr. Harold Macmillan during his visit to Washington in June. Such a large measure of agreement between the three leading industrial countries provides a hope that the increases in quotas which are likely to be agreed upon at New Delhi will be sufficiently large to make a real contribution to the solution of this problem.

Two Thirds Capacity

The economy as a whole continues to take the recession in the steel industry remarkably calmly. In August the industry was operating at only 70 per cent of capacity. Under normal circumstances this would be considered a serious state of affairs even during a holiday month. Most people have decided, at least outside the steel industry, that for one reason and another the drop in steel output is abnormal and temporary.

Optimism is based largely on the fact that the recession is mainly an inventory adjustment by steel users, and the whole situation has been confused by two factors. First, the record performance of the motor-car industry is helping to keep sheet mills very active, and secondly the loss of orders from abroad has not yet been as serious in its effect on turnover as some had anticipated. In any case there has been a good deal of optimistic talk in western Europe about the trend of steel demand and a further recovery in the level of industrial activity in the United States is expected to take the petroleum industry with it and hence the world demand for steel tubes. In this country the demand for tubes was one of the first to ease off when the current recession began. Altogether the fall in demand in steel from the capital goods industries and from export markets has been offset by other markets.

Short time working is now widespread in all sections except sheet and tinplate although this is masked to some extent by the holidays. Inevitably at the present time the industry's development programme comes under fire. The next stage of the plan covering the years up to 1962 was based on the assumption that world economic activity would continue to expand and that it would be accompanied by a rapidly rising rate of technical change and labour productivity. All the figures so far as this country are concerned suggest that the rate of progress will be slow in the next few years after a period of industrial stagnation. The steel industry is therefore faced with the unenviable task of deciding whether it should retain its optimistic assumptions of a year or two ago or whether it should extrapolate available statistics and modify, at least temporarily, its development plans.

Aeronauticists Together

For the first time in the history of aviation aeronautical scientists and research engineers from all over the world, including Russia and China, have recently met to pool their knowledge and discuss their problems. The occasion was the first International Congress at Madrid, organised by the International Council of the Aeronautical Sciences, a body whose object is "to encourage the free interchange of information on all phases of mechanical flight." Sheltered from the blazing Spanish sun, the main sessions took place in the gracious Salon de Actos at the Instituto National de Prevision, in air-conditioned arm-chair comfort and, above all, with a well-balanced audible acoustic arrangements, and up-to-the-minute IBM radio interpreter units.

The International Council of the Aeronautical Sciences came into being under American impetus—the idea of a "world wide forum" emanating from Mr. Harry F. Guggenheim, son of American aviation's most generous benefactor, Daniel, and financial assistance being derived from the income from the Daniel and Florence Guggenheim Memorial Fund. It was therefore appropriate that the congress should also be the occasion of the first Daniel and Florence Guggenheim Memorial lecture, given by the man who is generally acknowledged to be the greatest living aerodynamicist and who belongs equally to the two continents that have contributed most to the aeronautical sciences, Dr. Theodore von Kármán. Brief extracts from his paper on "Some Significant Developments in Aerodynamics since 1946" will be published in ENGINEERING next week and a general review of the congress programme will appear at a later date.

Red Elephant hits back

London Transport have published hard hitting comments on a paper critical of their organisation read by Mr. Norman Morton, general manager and engineer, Sunderland Corporation Transport Department to the annual conference of the Municipal Passenger Transport Association at Blackpool last week. Mr. Norman Morton argued that London Transport were too big to be organised efficiently, that there was no justification for a specially designed and higher costing London bus, that London bus maintenance was too expensive and inflexible and that fares were too high, comparing unfavourably with those ruling in the provinces. The paper was a vigorous critique of the report of the Chambers Committee of Inquiry of 1953, who did not find valid evidence to support such criticisms. The committee, said Mr. Morton, "made a cardinal error" in not appreciating that the weaknesses referred to in their report were "associated with the size of the undertaking and its method of control."

London Transport's reply strongly suggests that Mr. Morton got hold of the wrong end of the stick and misinterpreted both fact and opinion. The Chambers Committee, they say, considered that the undertaking was conducted "efficiently and with due regard to economy." They said that a reduction in the size of the area would not lead to economies or more efficient working but rather the reverse. Traffic conditions—over 250,000 people are transported by the undertaking's road vehicles between 7 and 10 a.m. and are taken home again in a somewhat shorter time—are such that they fully justify the decision to standardise the bus fleet as a special London type, at extra cost. The Chambers Committee fully concurred with this.

Mr. Morton's charges concerning high maintenance costs were countered at length. They related to 1953 "when bus maintenance procedures were in a stage of transition," and before the opening of the new Aldenham Works (in 1956). Allowing for changed price levels, expenditure on maintenance per bus was reduced by 10 per cent between 1953 and 1957. Moreover, London Transport led to the abandonment of the practice of regular major docking. The overhauling of engineering units, such as engines, steering mechanisms and gear boxes, is now "not on a time or mileage basis, but only when a particular unit requires attention." This radical change in maintenance practice is leading to substantial economies. Finally, the question of bus fares, say London Transport, cannot be considered in isolation from the underground train system which would otherwise be a heavy charge on the rates. The two are inseparable components of a service to Londoners for which they only pay part of the cost.

In the review, *London Transport in* 1957, just published, it is pointed out that during 1957 the LTE fully paid its way for the first time since 1948 and were able to make the minimum contribution of £5½ million to the central charges of the BTC.

Letters to the Editor

FLYING BUSINESS MEN

SIR, The decision of the Ministry of Transport and Civil Aviation to close Croydon Airport causes my co-directors and myself considerable concern. Our company, and many others operating private aircraft specifically for the purpose of furthering home and export business, must have the use of an airfield near London in order to operate with speed and efficiency.

With the closure of Hendon and Northolt, Croydon is the only airfield available to us within easy reach of London.

Apart from this, Croydon Aerodrome is regularly used by commercial operators, by ambulance services, by the Press, by flying clubs and, ironically enough, by the RAF and USAF as an alternative landing ground when poor weather conditions prevail at Gatwick. So far no suitable alternative is proposed. Surely the Minister of Transport and Civil Aviation should think again before prejudicing the efficiency of industries already handicapped by bureaucracy, and hamstrung by taxation.

Yours faithfully,

DAVID BROWN, JR.

David Brown Industries Limited,
Huddersfield.
10 September, 1958.

Editor's Note: A spokesman of the Ministry of Transport and Civil Aviation has commented on Mr. Brown's letter as follows. "The flying tenants at Croydon have been offered accommodation and flying rights at Biggin Hill as tenants of the Air Ministry—this is subject to the results of consultation with the County Planning Authority. Gatwick Airport is not available to flying clubs, but it is, of course, open to private aircraft equipped with radio, presumably the type of "executive" aircraft to which your correspondent refers. There are also a number of other aerodromes in the London area operated by the Ministry of Transport and Civil Aviation, by local authorities or private owners."

STRAIN HARDENING OF CYLINDERS

SIR, It would seem that Dr. Crossland and I have considered the question of initial yield in cylinders under internal pressure from different viewpoints; he is an engineer with a background of elastic theory, while I am a metallurgist exploring strain-hardening behaviour beyond the elastic range. He regards strains in the order of two or three times the elastic deformation as important, whereas I should discount them. They lie on a somewhat exaggerated form of the fillet which invariably connects the elastic line with the strain hardening curve proper, and are attributable to the same basic cause, namely, the gradual spread of the plasticising process through the metal. To avoid such complications, I deliberately confined my analysis to conditions where the strain-hardening curve becomes fully operative.

With all humility I submit that it is not I but Dr. Crossland who acts arbitrarily in his retention of tan ϕ as the representative true shear strain in torsion. I have merely accepted, and interpreted, the orthodox definition of principal shear strain used conventionally throughout plastic theory, namely

$$\gamma_{13} = \eta_1 - \eta_3 = \ln \frac{L_1}{L_0} - \ln \frac{L_3}{L_0} = \ln \frac{L_1}{L_3}$$

For correlation with the principal direct strains, it is essential that the shear strain shall, like them, be expressed as a natural logarithm, and to use a tangent for the purpose, except as an approximation at small values, is inconsistent with mathematical integrity. Moreover, this definition fulfils the postulate of constancy of volume—that the sum of the three principal shear strains, like that of the principal direct strains, shall be zero.

Surely, by preserving a consistent approach,

Continuing Letters to the Editor

with compatible definitions for both forms of strain, there is more hope of finding a satisfactory way of modulating from one mode of deformation to another, which, to my mind, is the paramount problem in this field awaiting solution to-day.

Yours faithfully,

E. VOCE.

Copper Development Association,
55 South Audley Street,
London, S.W.1.
11 September, 1958.

LINEAR FUNCTION

SIR, Although I was considerably amused by Capricorn's account of the experiment Professor Saunders described when presenting his presidential address to the Engineering Section of the British Association (Plain Words, 5 September), nevertheless I feel that some comment is required. Probably we have all produced amazingly clear evidence of relations, by a process of trial and error, even when the data examined has little more meaning than that used by Professor Saunders, but we are hardly justified in calling our efforts statistical analysis. The proper use of statistical techniques in the Capricorn context is limited to estimating a probability as an objective assessment of the reliability of some working hypothesis; if there is no hypothesis it may only mislead to analyse statistically.

However, to return to Professor Saunders' experiment—since it is stated that the original construction of the graph was at random the function x^2y will behave as the function x^2 masked by a random factor y; similarly, the function $\log_e xy_{not}$ will relate to the function $\log_e x$ together with a random interference from a variable y_{not}. Now as both x^2 and $\log_e x$ increase as x (positive) increases, no reader of ENGINEERING will be surprised that a plot of x^2y against $\log_e x\,y_{not}$ should demonstrate some apparent trend, which may even appear linear over certain ranges of variables. Not the linear trend but only the markedness of it is in question.

Anyone who is prepared to do the necessary arithmetic (after making plausible assumptions about the range of values in Professor Saunders' original graph) will find that the correlation coefficient between x^2y and $\log_e xy_{not}$ can be expected to be of the order of 0·4 which, on reference to the appropriate tables, is found to be highly significant for a sample of 100. Thus, although the anecdote is good, Professor Saunders' straight line is no more surprising than the fact that the time taken to read Capricorn's articles tends to increase with the number of words he writes.

Yours faithfully,

R. J. TAYLOR.

Operational Research Department,
British Iron and Steel Research Association,
11 Park Lane, London, W.1.
12 September, 1958.

GEARS FOR TURBINES

Tooth forms based on 20° and 16° pressure-angle basic rack profiles, and those produced by a hob of 16° flank angle in the axial plane, as developed by the marine gearing industry, are specified in the new British Standard *Gears for Turbine and Similar Drives:* Part 2, *Tooth Form and Pitches* (B.S. 1807 : Part 2 : 1958). A table relating to 20° and 16° pressure-angle basic rack-tooth profiles lists normal diametral pitch, normal pitch and module; and a second table lists pitches in terms of the axial pitch of the hob.

Copies of the Standard may be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W.1, price 4*s*., plus postage. Part 1 of this British Standard was published in 1952 and dealt with accuracy.

Plant and Equipment

LORRY LOADER

The Hiab hydraulic loader will lift 2 tons and derives its power from the power take-off on the engine.

A hydraulic loader with a handling capacity up to 2 tons is being marketed by George Cohen, Sons and Company Limited, Wood Lane, London, W.12. In the illustration it is shown mounted on an Albion Chieftan lorry. The "Hiab" loader consists of a centrally mounted articulated boom, operated by two hydraulic rams arranged as it were in tandem. It is capable of slewing through 180° to give complete coverage of the vehicle's load area and to allow loads to be handled with equal efficiency on both sides of the truck. Power is supplied by a multi-cylinder pump driven from the power take-off of the vehicle engine. Designed as a single unit, it can be fitted to virtually any type of load-carrying vehicle with a capacity of 5 tons or more without appreciably reducing the load area. The Hiab is bolted direct to the chassis immediately behind the driver's cab.

Hydraulic jacks, one on each side of the vehicle, are provided to relieve the strain on the chassis when lifting maximum loads and to give added stability on uneven ground. Dual controls are fitted as standard on both sides of the truck so that the load is in view of the operator, and under full control, the whole time. When not in use, it is folded away behind the cab. A 1 ton model is also available.

SCIENCE IN FILMS

Realisation of the part that films can play in aiding scientific research work and in the spreading of technical information has led, among other developments, to a continual growth in the membership of the Scientific Film Association. In view of the consequent increase in the demands on its services, the Association has moved to new headquarters, at 3 Belgrave Square, London, S.W.1, telephone BELgravia 6188. These premises have been made available by Aslib and it is expected that the closer relationship now subsisting between the two bodies will introduce the work of the Scientific Film Association to many persons and firms concerned with documented information of all kinds.

Another development of the Association is its intention to establish four new sections, to cater for the individual interests of its members, namely, a medical section, an industrial section, a research film section, and a popularisation of science section. Inaugural meetings of these new divisions of the Association are to be spread over the next few weeks but they will be open only to members of the Association. The first meeting of the parent body during the coming winter session will be held at Shell-Mex House, London, W.C.2, to discuss scientific films in the Soviet Union.

Obituary

HARRY S. BROOM

With the death of Harry Skeet Broom, which, we regret to record, took place on 12 September, Britain has lost another of the pioneers who commenced their careers on a wage of 5*s*. a week and whose untiring efforts during a long working life have led to the engineering industry in Britain achieving its present high level of efficiency and importance. His founding and development of Broom and Wade Limited, of High Wycombe, Buckinghamshire, is an encouraging story of success from small beginnings.

Born at Moulton, Norfolk, on 7 July, 1875, the seventh child of a farming family, he was apprenticed at the age of 15 to an engineering shop in Norwich. Studying in his spare time, he gained a prize for his design for a plunger pump. He later obtained a position in the works of Davey, Paxman and Company Limited, where he met his future partner and collaborator, Jethro Wade. He also held a position with the Lindy British Refrigerating Company.

When still only 20 years of age, he constructed a refrigerating plant which led him to make a detailed study of compressed-air problems. In turn, this led to the founding of his firm, Broom and Wade, in 1898. Their beginnings were of the smallest. While Wade was building their first workshop—a shed in a High Wycombe cornfield—Broom and two apprentices took on any odd jobs that were available to pay for it. Their only assets a 6 in lathe built by Broom, a few technical books, and some £20 in cash; the partners' first venture was to construct wood-working machines for the local furniture-making industry.

Their belief in the importance of compressed air in the engineering field resulted in the firm's first "large" order—for 71 air compressors for railway brakes for London's Underground. This was followed by an agency for the Hyatt Roller Bearing Company and, later, to Broom becoming a director of Vauxhall Motors Limited, Delco Remy and Hyatt, and Frigidaire. During the first world war, they produced 4·5 howitzer shells and during the last war much time was spent on making Churchill tanks. At the present day, the firm find employment for some 1,400 persons at their High Wycombe headquarters alone. They have subsidiary companies in Australia, Canada and South Africa, and agents throughout the world.

Broom was active in the business until quite recently and took an interest in a variety of social activities, including yachting and hunting. He was elected a member of the Institution of Mechanical Engineers in 1919 and had served for a period as President of the British Compressed Air Society.

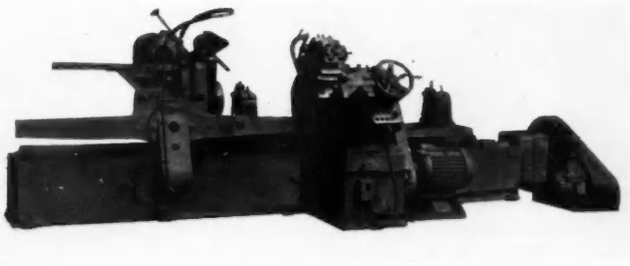
Continuing **Plant and Equipment**

GRINDING AND FLUTING ROLLS ON ONE MACHINE

Grinding, longitudinal and spiral fluting of flour-mill rolls can all be carried out on the new machine introduced by Thomas Robinson and Son Limited, Rochdale. The machine will take rolls up to 60 in long and 24 in diameter. Auxiliary equipment, which includes a special driving unit, can be supplied for the grinding only of rolls up to 32 in diameter.

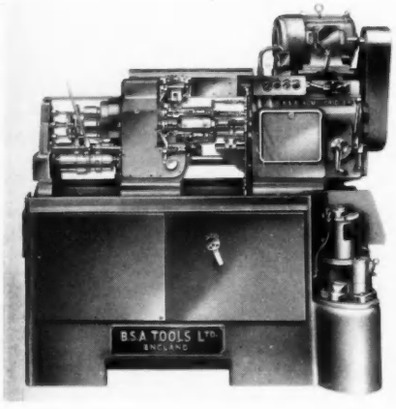
The head which carries both the grinding and fluting tools is adjustable for either operation by means of clamping screws which enable it to be swivelled about a central pivot. A hardened and ground steel spindle, running in self-lubricating gunmetal bearings, and driven by a 7½ h.p. motor through V-belts, carries the grinding wheel. When it is being ground the roll is rotated by a 1½ h.p. motor through a variable speed V-belt drive, worm reduction gearing and a dog clutch. Engagement of this clutch disengages the dog clutch used for fluting.

Two tool boxes mounted at the rear of the grinding wheel carry the fluting tools. Fine feed screws and graduated collars control the depth of the fluting cut. A lifting lever fitted to the boxes, and worked by stops fixed to the table, lifts the tool off the roll on the table return stroke. Only one tool is needed for fluting 13 or more cuts per inch; two tools are used when 12 or less cuts per inch are required. A pendulum lever, lifted automatically by a steel slide, effects the spacing of the flutes through a ratchet and pawl mechanism and a worm drive. Twisting of the roll for spiral fluting is by means of a block attached to the worm casing and moving in a machine-cut slide in a sine bar.



Longitudinal and spiral fluting as well as grinding of flour mill rolls can be carried out on the Robinson combined machine.

The table is driven by a 2 h.p. reversing motor through a two-speed gearbox and a square-threaded screw and nut. It is reversed electrically, either by stops on the machine table or manually, as required. All the motors on the machine are controlled from a push-button panel on the headstock.



SMALL SIX-SPINDLE AUTOMATIC

The latest addition to the well known B.S.A. Acme-Gridley multi-spindle bar automatics is the $\frac{7}{16}$ in six-spindle machine. Made and sold by B.S.A. Tools Limited, Mackadown Lane, Kitts Green, Birmingham, 33, the machine has all the basic features of the larger models in the B.S.A. Acme-Gridley range, and is particularly easy to set up and operate, the tooling area, cams and change gears being very accessible. The machine is only 5 ft 6 in long, and its height enables the operator to work at a comfortable stance.

Independently operated tool slides enable what are normally regarded as secondary operations to be included in the primary tooling set-up.

Having all the basic features of the standard B.S.A. Acme-Gridley range, the new six-spindle machine is of $\frac{7}{16}$ in capacity.

RELAY PILOT VALVE

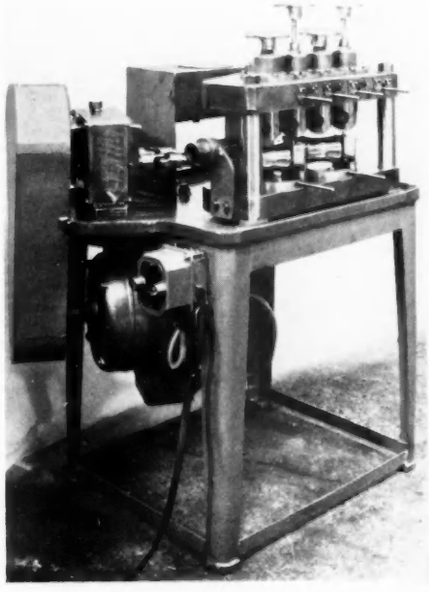
A high-capacity relay pilot valve for converting standard pneumatic or hydraulic cylinders to double-acting power positioners is now available from Hagan Corporation (Canada) Limited, Toronto, Ontario, Canada. It converts input air signals to pneumatic or hydraulic signals up to 150 lb per sq. in for actuating power pistons, diaphragm motors and rotary vanes. Standard input signal range is 0 to 30 lb per sq. in.

A conventional application is the positioning of large butterfly valves in response to signals from a remote control point. The air signal acts on a diaphragm in the positioner, displacing the small servo valve and sending air or hydraulic pressure to either end of the power cylinder. This, in turn, actuates the butterfly valve. The same motion is transmitted through follow-up linkage to the positioner cam, returning the servo valve to the null position when the butterfly valve reaches the position corresponding to the air signal value.

OIL BURNER MOTORS

The T series of fractional horse power motors by Crompton Parkinson Limited, Crompton House, Aldwych, London, W.C.2, has been extended by the addition of models which have flanges to comply with American NEMA standards for oil burners. They are available in drop-proof form in sizes from $\frac{1}{8}$ h.p. to 0·95 h.p. three phase, and from $\frac{3}{8}$ to $\frac{1}{2}$ h.p. single phase, and in totally enclosed form from $\frac{1}{8}$ to $\frac{1}{2}$ h.p. three phase and $\frac{1}{3}$ to $\frac{1}{2}$ h.p. single phase.

STRAIGHTENING ROCKER SHAFTS



Specially designed for straightening hollow rocker shafts used in car engines, the machine illustrated on the left is made by the Bronx Engineering Company Limited, Lye, near Stourbridge, Worcestershire. It straightens rocker shafts of high carbon seamless steel tube from 0·6680 in to 0·8736 in diameter, in lengths of 14½ in and above. Shafts are normalised and then passed through the machine prior to machining. After machining they go once more through the straightening rolls and they are then ready for the final operation of centreless grinding. Prior to straightening before the final operation, shafts were running out of straight to the extent of 0·025 in to 0·036 in. A single pass through the machine at 100 ft per minute reduced the bow to 0·0015 in for shafts up to 14½ in long and 0·0035 in for those up to 20 in long.

The machine is simple in principle, as can be seen from the illustration. There are four upper rolls, all idle, and two lower ones, both driven through universal couplings from a common gearbox and a 6 h.p. motor. Angular adjustment is provided on the lower rolls, and both angular and vertical adjustment on the upper ones. All the rolls are of heat-treated alloy steel, mounted in needle roller bearings. A drip-feed paraffin tank is provided, to assist in gripping the rocker shafts during straightening, and to keep the roll surfaces clean.

Seamless steel rocker shafts for car engines are straightened at 100 ft per min by this Bronx six-roll machine.

Continuing **Plant and Equipment**

FINE DETAIL ENLARGING

A photographic enlarger that will give as good, or better, results as the most expert of " dodging," but which is virtually push-button operated, has now been produced by EMI Electronics Limited, Hayes, Middlesex. It is shown in Fig. 1 while Figs. 2 and 3 give a comparison of enlargements from the same negative, emphasising the extra detail that can be obtained.

The principle is similar to that of the LogEtronic contact printer made by the same firm—that is, a light beam scans the negative, below which is a photomultiplier that integrates the intensity according to the exposure index. A second photomultiplier (No.1 in Fig. 4) receives the beam after it has passed through the negative (by reflection from a beam splitter) and adjusts the beam instantaneously as it passes from a dense region to a thin one, and vice versa. Thus any detail that is present on the negative is brought out on the print; the factors for paper, speed and desired print density are pre-set and any number of identical prints can be run off. The degree of shading is also under the operators control.

The beam produced by the cathode ray tube is cold and highly actinic, scanning the negative once per second. Any negative from 35 mm to ½ plate can be covered. The final print area has a maximum of 30 in by 40 in and, when using a 3 in lens, the magnification is × 11; with a 7 in lense it is × 10 approximately. Manual focusing with a positive lock is used. Power is drawn from the 230/250 V 50/60 cycle mains single phase and about 2 A is required.

Fig. 1 (left) Automatic adjustment of the scanning beam of the enlarger enables fine detail to be brought out from the negative.

Figs. 2 and 3 Although the intensity of the white surfaces is the same in both prints, that on the right shows clearly the detail actually present on the negative but lost in a conventional enlargement.

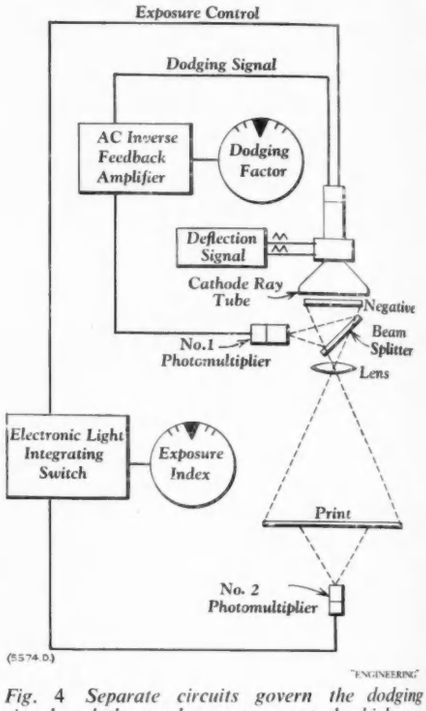
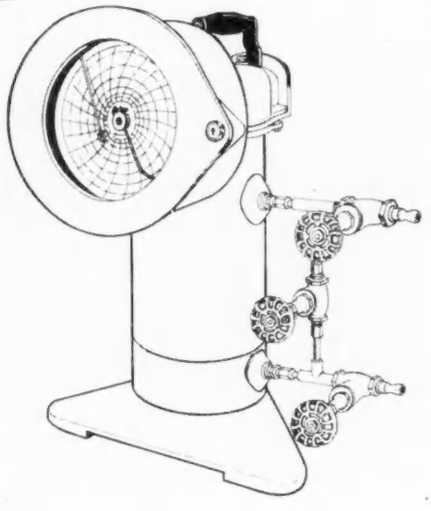


Fig. 4 Separate circuits govern the dodging signal and the total exposure control which can be pre-set.

GAS FLOW RECORDER

There are many occasions on which it is required to know the flow of gas in a main, and a portable instrument for the purpose is being marketed by Walker, Crosweller and Company Limited, Cheltenham. It will be shown at the forthcoming Industrial Fuel Efficiency Exhibition at Olympia. Known as the " Arkon " recorder, it can be used in mains from 4 in diameter upwards. Since its action is that of a pitot tube, the gas does not have to be shut off and spot tests can be carried out as required. To take a reading, the main is drilled and tapped for a 1 in gas thread and a straight pitot tube inserted. The gas flow is then recorded on a circular chart in cubic feet per hour. After the test has been completed, the pitot tube is removed and replaced by a plug; tests can then be made at the same point at any time simply by removing the plug. A table is provided for correcting the recorded flow to the size of the main being checked.

The head and stand of the instrument, which is shown in the attached illustration, are of cast aluminium and the body is of brass sheet. The two connecting cocks are standard ¼ in, and are fitted with nipples for ½ in hose. Overall dimensions are 20½ in high and 14½ in wide. The chart's diameter is 8 in, reading in 0 to 10 flow units, revolves once in 24 hours, and is driven by clockwork. The standard instrument has a differential pressure range of 10 mm and is suitable for pressures of up to 30 lb per sq. in.



Portable recorder for gas flows

FINNED TUBE

A form of heat exchanger tubing has been developed by Tube Products Limited, Oldbury, Worcestershire, in which the base tube consists of normalised " Tru-Wel " boiler tube on which a helix of mild steel fin has been resistance-welded. This welding method eliminates the introduction of any other material, and the resulting tubing is slightly stronger, both transversely and longitudinally, than the original base tube, without any additional heat treatment. The range of sizes available is from 1 in to 5 in outside diameter of base tube with wall thicknesses up to ¼ in, and fin heights up to ½ in. Fin thickness can range from 0·05 in to 0·08 in and fin pitch up to 7 fins per in, depending on fin thickness.

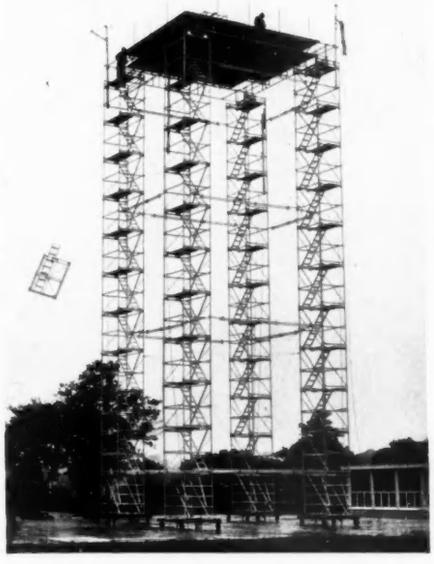
REDESIGNED DUMPER

A redesigned version of their Muir-Hill 3S 1 yd dumper is now available from E. Boydell and Company Limited, Old Trafford, Manchester 16. This embodies a 7½ h.p. Petter engine giving greater power; in addition the body capacity has also been increased, a new body catch fitted, higher gear ratios incorporated and the weight reduced. With a heaped body capacity of 30 cu. ft the dumper is capable of 12·5 m.p.h. in top gear.

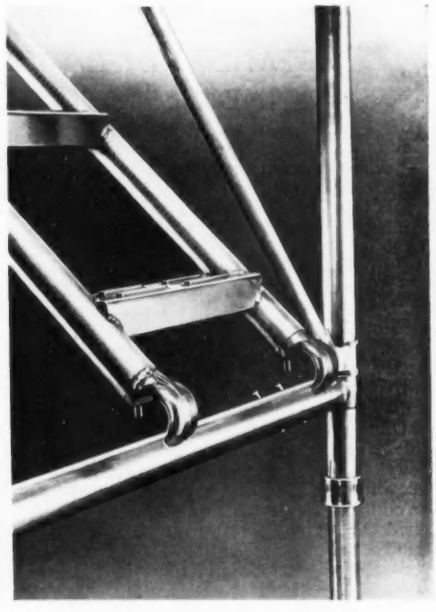
MOBILE STAGING REACHES 100 FT

A demonstration of their Zip-Up staging was given recently by Access Equipment Limited, Maylands Avenue, Hemel Hempstead, Hertfordshire. The requirement was a staging 100 ft high to enable the interior of the Waalwyk (Holland) Cathedral to be cleaned. A second requirement was that it should be movable in order to reach all parts of the building. The result was achieved by the use of four towers, 70 ft high, built of the firm's standard Zip-Up units, mounted on castors and linked together by struts and tie-wires to form a single unit. On the top was built, of ½ in laminated wood, a platform 27 ft square. On this was erected a second tower, 30 ft high, also mounted on castors to enable it to be wheeled about the platform. The entire structure was erected by eight men in four hours only, the men being new to the work. Dismantled, the sections can all be stored in a single pantechnicon for transport to another site.

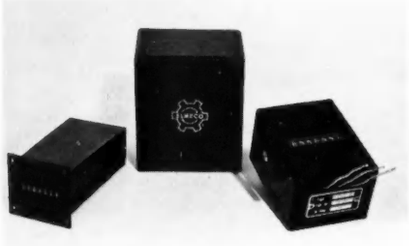
Apart from the mild steel chassis on which the first stage towers were mounted, the larger-size castors used for them, and the light alloy beams uniting the four towers, the whole was composed of standard light-alloy units. Each of the main towers was made of 11 units (they fold flat for transport), and the steel base-frames (which also fold flat) can be used for equipment trolleys. Resin-bonded plywood is used for the flooring of the platform and for the floor of each section. The whole structure weighs 7,300 lb and the safe load on the upper platform is 1 ton distributed. The 30 ft upper tower weighs 430 lb. The structure can be moved as a whole by unlocking the main castors and pushing at the base. Erection is by the davits mounted on the towers, and which are moved up as the stages are added. Standing free above the staging these can lift 150 lb and are useful for raising cleaning equipment to the platform. Clamped against the frame, their lifting capacity is increased to 500 lb.



A complete section, in the folded condition, is hoisted up by the davit for this 100 ft high staging. The structure was erected in 32 man-hours.



The locking hooks on Zip-Up staging.



IMPULSE COUNTER

A new type of electro-magnetic impulse counter, manufactured by Elmeco A.-G., Zurich, is now available in this country, from Inglis Knibb and Company, 20/21 Tooks Court, Cursitor Street, London, E.C.4. The counter is intended to fill the gap between existing types of electro-magnetic counters and the electronic types; it can be supplied with mechanical, electro-magnetic, or combined mechanical/electromagnetic resetting devices.

The counter has 5, 6 or 7 figures and is operated by a stepping motor from which the number drums are driven by a plastic belt. The result is a silent machine capable of accurate counting at a sustained rate of 30 impulses per second, which can be increased to 60 impulses per second for limited periods; the operating current is low. The guaranteed life at 30 impulses per second is 300,000,000 counts. No adjustment or lubrication is necessary and the counters are available for either bench work or panel mounting.

Motor driven, the counter is silent in operation and capable of recording up to 60 impulses per second.

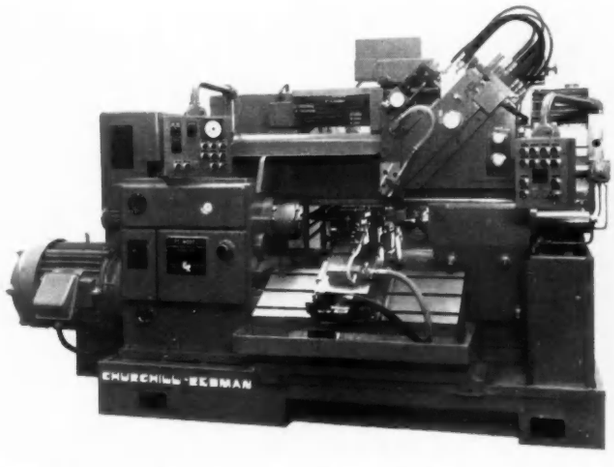
MULTI-TOOL AND PROFILE TURNING

Now in production, the P5 automatic multi-tool and profile-turning lathe, made by Churchill-Redman Limited, Halifax, is available in two models, of 20 in and 40 in between centres. The lathe will swing 15 in diameter over the bed and 9 in over the saddle.

Designed on the unit principle, the machine, of which a general view is shown in the accompanying illustration, can be built up with maximum flexibility to suit a user's requirements. It is entirely push-button controlled and is operated from two push-button stations, one at each end of the bed; all machine movements can be operated separately for setting purposes. The lathe can be loaded manually, from a hopper, or from an automatic transfer feed. Basically, the machine is equipped with an overhead profile-turning carriage and a rear auxiliary in-feed slide. A front auxiliary slide is available which, like the rear one, can be used in a variety of ways. The slides can be arranged with a traverse motion, or swivelled to any angle. They can be used as multi-tool turning slides or as additional profile-turning slides.

The profiling carriage is mounted on separate slideways, with hardened wearing strips, and has an infinitely-variable feed rate of 0 to 30 in per min in the lower range and 60 in per min in the higher. Trip gear is provided for automatic changing of feed rate at any point in the cycle. Carriage return rate is 20 ft per min. Spindle speeds are from 250 to 2,000 r.p.m., or 125 to 1,000 r.p.m. with pick-off gears, and there is an automatic spindle speed change in a 2 to 1 ratio by means of hydraulic clutches.

As the rate of metal removal is high, the question of chip clearance is important. A split vertical bed, coupled with the use of an overhead profiling carriage ensures that chips have a clear fall to the machine base, whence they can be removed from the rear. If desired an automatic swarf conveyor can be fitted to elevate swarf to a bin for disposal.



The new Churchill-Redman lathe provides for automatic profile turning or multi-tool work, and has many extra fittings available.

Continuing **Plant and Equipment**

STANDARDISED PONTOON AND FERRYING UNITS

The multi-purpose flotation unit made by Thos. Storey—the " Uniflote " —has now been in use for 12 months. During that period a number of accessories have been designed and experience gained in a variety of applications, both military and civil.

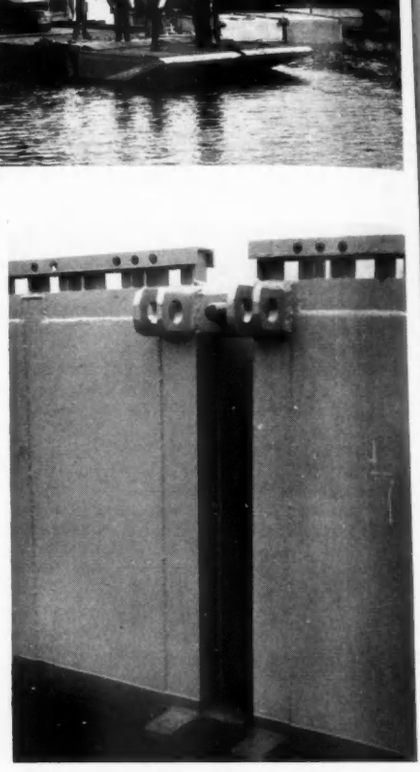
The basic Uniflote unit is a simple all-welded steel box 17 ft 4 in long by 8 ft wide by 4, 6 or 8 ft deep. A 4 ft unit built of $\frac{3}{16}$ in plate weighs 3·01 tons and has an unloaded draught of 9·3 in. Adjacent units are linked up by the top and bottom couplers shown in the lower illustration. The bottom couplers consist of " over " and " under " grips and are interlocked by merely ducking the corner and drawing the units together; the upper couplers comprise a male and female and the connection is made by driving a tapered pin through the coupling. When two units are coupled top and bottom the connection is rigid and no relative motion is possible between the units.

Units can be coupled end to end, or side by side. There are four sets of top and bottom couplers along each side of a unit, the spacing allowing the ends of two side-by-side units to be connected to the side of a third. Each unit is divided internally into three tanks by watertight bulkheads which allow it to be partially submerged if required by pumping in water ballast. Manholes and vents in the top surface enable the tanks to be " blown " when necessary. Channel-section gunwales along each side serve a variety of purposes, including providing attachments for hawsers, hoses and so on, and forming joists to carry flooring. The size of the unit keeps it just within the limits of a practicable load for road or railway.

In conception the Uniflote is first-class and the coupling system is beautiful in its simplicity and effectiveness. Experience has shown that four 4 ft units can be connected end to end (so forming a beam 70 ft long by an effective 3 ft 6 in deep between couplings, i.e., a length/depth ratio of 20 to 1) and will successfully ride out any tidal movement to which it might be subjected. A whole host of secondary connectors are now available that will allow longer and wider formations of Uniflotes to be built having sufficient flexibility to articulate under wave action.

Bow and stern units enable the pontoon formations to be converted into barges and with Harbormaster units fitted they can be propelled under power. Uniflotes have been successfully used for building floating landing stages and Centurion tank transporters. They have been used as pontoons supporting Bailey bridging, as can be seen in the upper illustration. A number of booklets and manuals related to the use of Uniflotes are to be had from the makers, Thos. Storey (Engineers) Limited of Stockport, Cheshire, or from their office at 6 Victoria Street, Westminster, London, S.W.1. The makers have considered the possibility of using them for pontoon bridges, floating cranes, waterborne pile drivers and salvage pontoons. At the demonstration where the accompanying photographs were taken, after the crawler crane had been re-landed, a Sikorski 55 helicopter of BEA landed and took-off several times from the raft without difficulty.

Uniflotes used for a power-propelled raft and (in the background) as a floating pier for Bailey bridging. After off-loading the crane, a helicopter landed and took-off from the raft.



Top and bottom couplers of the Uniflote. All coupling is done from deck level.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

BOURNEMOUTH
" Fires and Explosions," by S. J. Emerson. Bournemouth Branch. Grand Hotel, Firvale Road, Bournemouth. Tues., 23 Sept., 8 p.m.

CROYDON
Film on paper making, introduced by E. E. Webb. South London Branch. Greyhound Hotel, High Street, Croydon. Thurs., 25 Sept., 8 p.m.

British Institute of Management

LONDON
Fourth Elbourne Memorial Lecture on " The Great To-Morrow," by the Earl of Verulam. Royal Commonwealth Society, Northumberland Avenue, W.C.2. Fri., 3 Oct., 8 p.m.

British Institution of Radio Engineers

LONDON
" Statistics in Radio and Television Manufacture," by A. I. Godfrey. London Section. London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1. Wed. 24 Sept., 6.30 p.m.*

Engineers' Guild

LONDON
Annual General Meeting. Discussion on " The Changing Pattern of Leadership," opened by Mr. A. R. Cooper. Metropolitan Branch. Caxton Hall, off Victoria Street, S.W.1. Tues., 23 Sept., 6 p.m.*

Illuminating Engineering Society

BATH
" Horticultural Lighting," by A. W. Gray. Bath and Bristol Centre. Offices of the South Western Electricity Board, Old Bridge, Bath. Mon., 22 Sept., 7 p.m.

Incorporated Plant Engineers

BIRMINGHAM
" Planned Maintenance," by A. F. R. Stedman. Birmingham Branch. Imperial Hotel, Temple Street, Birmingham. Fri., 26 Sept., 7.30 p.m.

SHEFFIELD
" Hydraulics," by F. H. Towler. Sheffield Branch. Grand Hotel, Sheffield. Thurs., 25 Sept., 7.30 p.m.

Institute of Welding

LONDON
" Welding in Low Temperatures," by D. Pratt. Wed., 24 Sept., 6.30 p.m.

Institution of Engineering Designers

BRADFORD
"Fan Cooled Worm Gear Reduction Units," by J. W. Peake. Yorkshire Branch. Midland Hotel, Bradford. Tues., 23 Sept., 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
Presidential Address by Professor J. Small. Tues., 7 Oct., 6.30 p.m.

Institution of Heating and Ventilating Engineers

BIRMINGHAM
Discussion on " The Clean Air Act and Its Effect on the Heating Engineer." Birmingham Branch. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. Tues., 23 Sept., 6.30 p.m.

Institution of Mechanical Engineers

NOTTINGHAM
Branch chairman's address. East Midlands Branch. Engineering Building, The University, Nottingham. Wed., 24 Sept., 7.30 p.m.*

Institution of Production Engineers

SHREWSBURY
Film on " Copy Turning." Shrewsbury Section. Technical College, Shrewsbury. Wed., 24 Sept., 7.30 p.m.

Liverpool Metallurgical Society

LIVERPOOL
Presidential Address on " Alternative Methods of Iron and Steel Production," by Dr. C. Bodsworth. Department of Metallurgy, University of Liverpool, 146 Brownlow Hill, Liverpool, 3. Thurs., 9 Oct., 7 p.m.

Modular Society

LONDON
Discussion on " Modular Assembly After Its Erection," and a display of drawings. Building Centre, Store Street, W.C.1. Wed., 24 Sept., 6 p.m.

Society of Chemical Industry

LONDON
" Corrosion Embrittlement: The Effect of Cathodically-Evolved Hydrogen on Iron and Nickel," by Professor Michel Smialowski, of the Polish Academy of Sciences, Warsaw. Corrosion Group. Wed., 1 Oct., 6.30 p.m.*

Society of Engineers

LONDON
" The Bridge over the River Kwai," by K. H. Best. Geological Society, Burlington House, W.1. Mon., 6 Oct., 5.30 p.m.*

Society of Instrument Technology

LONDON
" Frequency Response Analysis Using Describing Function Method," by Professor C. J. West. Manson House, Portland Place, W.1. Tues., 30 Sept., 6 p.m.*

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than three weeks before the date of the meeting.

* An asterisk is placed where it is understood that refreshments are available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury Square, London, W.C.1. (LANgham 5927.)
British Institute of Management, Management House, 80 Fetter Lane, London, E.C.4. (HOLborn 3456.)
British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1. (MUSeum 1901.)
Engineers' Guild, 78 Buckingham Gate, London, S.W.1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria Street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 12 The Parade, Solihull, Warwickshire. (Solihull 1111.)
Institute of Welding, 54 Princes Gate, Exhibition Road, London, S.W.7. (LANgham 7488.)
Institution of Engineering Designers, 38 Portland Place, London, W.1. (LANgham 8847.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan Square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield Street, London, W.1. (GROsvenor 5254.)
Liverpool Metallurgical Society, Greenhithe, Grosvenor Road, St. Helens, Lancs. (St. Helens 5879.)
Modular Society, 22 Buckingham Street, London, W.C.2. (TRAfalgar 4567.)
Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. (BELgrave 3681.)
Society of Engineers, 17 Victoria Street, London, S.W.1. (ABBey 7244.)
Society of Instrument Technology, 20 Queen Anne Street, London, W.1. (LANgham 4251.)

Companies in the News

A Brush With Hawker Siddeley

The Brush Group are to be integrated more closely within the overall framework of the industrial activities of the Hawker Siddeley Group. This is part of a major process in reorganisation which will involve the creation of a number of separate divisions reflecting the various activities of the group as a whole. All aircraft interests will be concentrated under an Aviation Division, all industrial activities—including those hitherto carried on by the Brush Group—will be combined under an Industrial Division and other divisions may be formed, including an Administrative Division to control central group management.

It had been rumoured for some time that the Hawker Siddeley management were not satisfied with the operations of the Brush Group and that changes were imminent. The existing board of directors are to be dispersed. Some will be remaining with the Hawker Siddeley Group in various capacities, but the remainder will be leaving the group entirely. It is understood that among the latter are the present managing director, Mr. I. T. Morrow and Sir Harold Roxbee Cox.

Batteries Recharged

Increased output has enabled Oldham and Son Limited to absorb rising costs. In his annual report their chairman, Mr. John Oldham, reports higher sales in all divisions, despite increasingly competitive conditions. The reduction in profits —from £453,000 to £412,000—was due to increased expenditure on technical development and sales promotion designed to expand the company's range of production and to open up new sales outlets. The results, said Mr. Oldham, have been highly satisfactory and give him confidence that the group will continue to expand. "Our latest technical advances," he told shareholders, "have paved the way into new and valuable markets." The emphasis will continue to be on technical advance and on more intensive selling. Direct exports increased by more than 50 per cent and this despite what Mr. Oldham described as "keener than ever competition and the increased restriction of imports into certain countries due to increased local manufacture."

Oldham have manufacturing and distributing centres in France, South and Central Africa, India and Australia. The French company have continued to be the leading suppliers of miners' lamps to the coal industry and, like the parent company, have added a number of new lines to their range of products. Mr. Oldham stressed the importance of the French base "against the background of the forthcoming development of the Common Market." In a recent tour of Africa Mr. Oldham noted economic and industrial developments likely to increase demand for the group's products. He also observed that Africa is increasingly being looked upon as "a promising field of investment" by other nations and he advocated further strengthening of commercial links with Britain through the enterprise of individual companies.

The Chloride Electrical Storage Company Limited have recently opened a new factory for manufacturing automotive batteries in Salisbury, Southern Rhodesia. It has been equipped by the company's plant development department with equipment and machines specially designed for the conditions prevailing in Rhodesia.

Five-Fold Phoenix

The former railway workshops at Dundalk in Eire have recently become the property of the Dundalk Engineering Company. Five separate companies are now to be set up with a combined capital of about £1 million to use the old works. A certain amount of reconstruction and the installation of machinery will be necessary and during that time there must be a certain amount of redundancy.

The new companies will consist of a steel foundry making high-grade steel for cutlery and steel castings, a plant to make Heinkel miniature cars, a concern to make agricultural machinery, a general engineering workshop which will do repairing and maintenance work for the national transport monopoly and a concern to make chassis for heavy-duty passenger and commercial vehicles. The steel foundry will make a grade of steel which has up to the present been imported. The Heinkel plant has been bought by Dundalk Engineering Company in Germany and transferred to Ireland. It remains to be seen whether under Irish conditions all these projects can be turned into profitable businesses. Meanwhile, a small trading estate (for that is what it amounts to) has arisen phoenix-like out of the ashes of the Dundalk workshops.

Special Metals Stressed

Special metals and alloys have suffered a startling setback during the past few months and this is beginning to be reflected in the accounts of the manufacturing companies. One of the leaders, Murex Limited, report a fall of £41,000 in trading profits to £978,000 due to the fall in demand for both ferrous and non-ferrous metals in the latter part of this financial year. Their chairman, Sir Arthur Smout, told shareholders that cuts in the Defence Programme had aggravated the effect of the gradual recession and that "the persistent weakness" of the wolfram market had further contributed to the company's reverse.

Sir Arthur indicated that the products adversely affected by the recession so far as Murex are concerned were ferro-tungsten, low-carbon ferro-chrome, and the special metals and alloys of the Thermit metals group. There was also some reduction in the sales of tungsten carbide, tungsten and molybdenum rod and sheet, and molybdenum powder, partially offset by increased demands for tantalum products. The company suffered heavy stock losses—£80,000 was required to offset losses on stocks of wolfram—and can expect to do little else in a period of persistent price falls.

Looking ahead, Sir Arthur Smout foresees satisfactory prospects for Murex. The company's results, he warned, will always be liable to considerable fluctuations, but the group are very strong (with net current assets of nearly £4 million), and they are well placed technically to keep abreast of technical change. As the usage of certain products declines in consequence of changes in engineering design and techniques, it is the company's endeavour to replace them with other products of promise. Murex Research Laboratories said Sir Arthur, are doing "much valuable work" to this end.

German Big Four

Four of the largest German companies published their annual reports recently, providing a useful and up-to-date review of business trends in that country. The largest of these, Daimler-Benz AG (the others are Demag, Vereingite, Aluminium-Werke A.G., and Chemische Werke Huls AG) had a turnover of DM 1,791 million and trading profits of DM 660 million. They hold a controlling interest in Auto-Union GmbH and are the second largest makers of road vehicles in Germany. Output last year totalled nearly 124,000 vehicles, an increase of some 15 per cent on 1957. Their chairman, Dr. Konecke, noted that output during the first half of the current year shows an increase of 16 per cent over the corresponding period of 1957. Much of this was accounted for by higher exports, up 29 per cent, compared to a rise of 8 per cent in home sales. Dr. Konecke underlined the importance of good labour-management relations and expressed his "wholehearted support" for the national appeal for price discipline "which is to help maintain the present level of employment by means of expanded production."

Dr. Reuter, chairman of Demag, had a less cheerful outlook. His company's wide range of products enables them to absorb setbacks in particular sectors more easily but he noted nonetheless "a slow down in general economic development" in the West German engineering industry: "Future prospects and the level of employment are largely dependent on the investment possibilities which exist in the iron and steel, mining and building industries." He called for special efforts to "maintain and strengthen" the earning power and consequently the readiness to invest of these industries.

The report of the directors of Aluminium-Werke also noted that the German economy was being affected by "the weakening of international economic expansion." Their review of the progress of the German aluminium industry shows that although expansion continues (output in 1957 was 153,800 metric tons, 6,400 more than in 1956) it has been at a slower rate than either the rise in the national product or that of capital goods production. The company were unable to utilise their full capacity of 120,000 tons a year. The report of Chemische Werke Huls showed that the chemical industry is expanding at a much faster rate than almost any other sector of the German economy. Turnover in 1957 at DM 523 million was DM 46 million above that of 1956 and progress has continued despite increasing competition. The rise in the cost of labour and raw materials has been offset by a higher degree of capacity utilisation, but profits are lower because price cuts had to be made "in order to safeguard the company's share of the market." Increased competition, higher costs and a fall in the rate of expansion or profits seems to be a fairly general experience.

Loan from Germany

The raising of a loan of £4·2 million on the West German capital market by Anglo-American Corporation is a startling development in international finance. It is the first time since the 1914-18 war that a foreign company have succeeded in doing this and it may prove to be of world-wide significance. Anglo-American comment that the loan to be made by the Deutsche Bank will first enable the group to assist in strengthening the structure of the diamond trade in which they have large interests and, secondly, promote industrial development "by opening up a source of new capital for Southern Africa."

This interest in Africa by countries other than Britain was noted by Mr. John Oldham on a recent visit (see other note on this page). That German capital should now become available at interest rates the City of London could not better means that Western Germany is ready to invest abroad. The size of her reserves, built up over the past few years by her export industries, means that she can do so with private capital on a very substantial scale. It will be a major topic when finance ministers from all over the world foregather next month in New Delhi for the annual meeting of the International Monetary Fund and the World Bank.

George Kent in Malaya

The Malayan subsidiary of George Kent and Company have had to contend with difficult conditions during the year ended March 1958, resulting in a drop of 16 per cent in turnover and of 7 per cent in profits. In our note on this page last week we inadvertently identified these results with the parent company, whose turnover was, in fact, just over 7 per cent greater than the previous year at £5·9 million, and trading profits just over 2 per cent greater at £664,240.

Special Article

SATELLITE EXPERIENCE

Experiments Described at Ninth Astronautical Congress

ABOUT A YEAR ago the world was surprised to hear signals from outer space—transmissions from an artificial satellite. Now it can be seen that Sputnik I, launched on 4 October, signalled not only a new advance in technical ingenuity but also a re-orientation in technical thought. Space exploration became a subject no longer confined to the fiction shelves; the dilettante aura that surrounded long-range rocket design in the West was dispersed. Last week Britain made her "first real entry into space"—to use the words of the Minister of Supply—with the Black Knight rocket; overhead, comparatively neglected, circle various objects ranging in mass from a few pounds to well over a ton; attempts are being made to reach the Moon. Clearly, since the first Russian satellite rose over the horizon, on the eve of the 8th Annual Congress of the International Astronautical Federation, there has been no lack of progress in the field of rocket and satellite flight. The 9th Annual Congress of the same organisation has recently been held. The papers read there indicate the experience gained in this new field.

Firing Procedure

In a paper "The Explorers," Dr. Wernher von Braun gave an outline of the firing procedure for the Jupiter C missile that his team had used to put satellites into orbit. The missile takes off vertically under its thrust of 83,000 lb and during the 155 seconds burning time of the first stage, it is tilted into a trajectory which is approximately 40° inclined to the horizon at cutoff. A few seconds after cutoff, the booster—the combined tank and engine section of the first stage—is separated from the instrument compartment. This is done by igniting six explosive bolts which secure the compartment to the front end of the first stage. Wrapped around these bolts are coiled springs which have been pre-loaded during the assembly procedure. At the moment the powder charges destroy the bolts, the springs exert a gentle push on the instrument compartment and separate it cleanly from the booster. The velocity increment imparted to the instrument compartment by the springs is of the order of 2·6 ft per sec.

The so-called depletion technique is used to cut off the motor of the first stage. That is, shortly before the expected burnout time two contacts are energised. These sense the pressure in the fuel and the liquid oxygen pump discharge lines. Whichever pressure drops to zero first triggers a relay that, in turn, closes both propellent main valves controlling flow into the combustion chamber. In the launching of Explorer I, cutoff occurred after 157 seconds—two seconds later than expected. At the same time a timer was triggered to activate the separation mechanism 5 seconds later. This prevented the runup of the booster into the instrument compartment as a result of the gradual thrust decay.

In the near perfect vacuum such as the missile encounters at a cutoff point 58 miles above the earth's surface, there is no abrupt cessation of thrust. While thrust drops quite abruptly to a fraction of its original level, further decay is slow because all the gas in the combustion chamber, plus whatever fuel and liquid oxygen is trapped between the valves and the combustion chamber will expand or after-burn. This exerts a small but noticeable post-cutoff impulse on the booster.

From the point of separation, the two portions of the missile coasted through a vacuum trajectory until about 404 seconds from take-off. The apex was nearly attained at this time. During the free coasting period, the spatial attitude control system aligned the instrument compartment into an exactly horizontal position with respect to the earth's surface.

This was accomplished as follows. The same gyroscopes which had controlled the missile up to the cutoff point by means of jet vanes now (after separation) controlled a system of compressed-air nozzles mounted in the tail of the instrument compartment. The reaction thrust of the air nozzles tilted the entire nose section, complete with the spinning cluster of high-speed rockets, into the horizontal direction. The tilt actually occurred substantially faster than the tilt of the trajectory itself. This was done in order to give the residual errors sufficient time to decay.

Owing to the relatively crude cutoff technique, based only on propellent depletion, it was impossible to predict, prior to the launch, when the apex would be attained. It was for the same reason impossible to determine in advance the horizontal distance the missile would have traversed between take-off and apex. Because of the curvature of the earth and because the high-speed rocket launcher of the satellite must be in an exactly horizontal position over the local horizon, it was necessary to introduce some auxiliary tracking means to furnish additional information during the flight. Three independent methods were employed to determine the instant of apex as precisely as possible. First, the missile was tracked by radar. The radar plot was used to predict the instant and point in space at which the apex would be reached. Second, an accelerometer in the missile relayed, by means of telemetry, the velocity build-up of the first stage. Cutoff velocity was then fed to a simple ground computer which predicted the instant of apex transit. Third, a standard Doppler tracking network furnished the same information.

The results obtained with the three independent apex prediction methods were introduced into a small calculator which enabled the evaluation of the quality of the three inputs. For example, if one prediction was based upon readings of poor quality, it could be disregarded or its value in determining the average would be reduced to about 20 per cent of the weight of the other methods. Thus a reliable average of the apex predictions could be determined. The average was then used to set a timing device which despatched a radio signal to the missile, to fire the second stage. All this had to be accomplished in the four-minute interval between cutoff and apex.

In fact, it was not required to fire the second stage at apex but slightly prior to this instant. The second, third and fourth stages had burning times of about 5 seconds each and several seconds elapsed between firing one stage and burnout of the previous stage. Total elapsed time between firing one stage and fourth stage cutoff was about 24 seconds. Firing of the second stage had to occur therefore slightly before the apex point. With this lead time the vertical velocity component of the high-speed cluster would be exactly zero at the fourth stage cutoff.

From post-launch tracking data, it was learnt that the angle at which the fourth stage entered orbit was, in respect to the local horizon, as little as 0·81°—a remarkable accuracy in view of the many factors contributing to the error. However, Explorer I would still have orbited had the error been as high as 4°. The initial altitudes of the satellite were 225 miles at perigee and 1,594 miles at apogee, corresponding to a period of revolution of 114·78 minutes.

Intense Radiation

Sputnik Measurements

The Russian delegates were not tempted to follow the American example by describing the rockets and launching procedure used to put their satellites in orbit. Details were given, however, of some of the results achieved with Sputnik III. In "Exploration of the Upper Atmosphere with the Help of the Third Soviet Sputnik," the author, V. I. Krassovsky, described some of the geophysical investigations that have been carried out, with particular emphasis on the question of the sources of energy and heating in the upper atmosphere.

Prior to the launching of satellites, the temperature of atmospheric regions above 200 km was considered to be at considerably less than 1,000° K. The standpoint was confirmed by Soviet rocket experiments, and up till recently the so-called "rocket models" of a cold isothermal region of the atmosphere with small density were mostly in use. However, the data about the density of the atmosphere at 220 km obtained by observation of the rate of retardation of Sputnik I (3×10^{-13} grams per cc) made necessary a re-examination of accepted theories of density, temperature, and dynamics in the upper atmosphere. In particular the observation of satellite retarding confirmed a model of a hot and dense upper atmosphere. In this connection, determination of the density of the upper atmosphere by some other means presents particular interest, and for the purpose, the third sputnik was equipped with ionisation and magnetic manometers. It was established that after several revolutions of the sputnik around the earth, the emission of gas from the satellite's surface became negligible. After this initial period, the manometric data confirmed the retardation observations, and established that scale height (temperature) increases with altitude. The manometers indicated that at a height of 260 km the density is equal to 10^{-13} grams per cc and at 355 km, 9×10^{-15} grams per cc.

To investigate the ionisation distribution with height further, the third Soviet sputnik was equipped with an instrument for direct measurement of the concentration of charged particles in the ionosphere; the instrumentation also allowed measurement of the voltage of the body of the satellite in relation to the surrounding medium. The processing of the experimental readings is still in the initial stages, however, and therefore only preliminary information could be given. In fact, the author confined himself to measurements at two points in the first day's flight. The values observed were stated to be typical, although lower readings had also been obtained.

On 15 May this year, five to six hours after noon in the middle latitudes, the satellite was at an altitude of 795 km and had a negative potential of 6·4 V with respect to the surrounding medium. Taking into effect the photo-effect, the potential can only be accounted for if the electron effective temperature is not lower than 15,000° K. The concentration of positive ions determined by the instruments amounted to $1{\cdot}8 \times 10^5$ ions per cc. On the same day, one to two hours before noon, also in the middle latitudes but at a height of 242 km, the positive ion concentration proved to be $5{\cdot}2 \times 10^5$ ions per cc. The negative potential of the satellite was about 2 V and the effective electron temperature, 7,000° K.

The material obtained is thus of great relevance to the theories of the upper atmosphere. The large scale height for the electrons as well as

the high electron effective temperature agree well with a strongly heated upper atmosphere model.

A series of observations of extra-terrestrial phenomena were also to be carried out by means of the third sputnik. For instance, it was planned to investigate hard electromagnetic solar and cosmic X-ray and gamma ray emissions; the experiment was designed to work in the absence of the parasitic background created by cosmic rays in the low dense layers of the atmosphere. At the same time there was an experiment designed to discover electron fluxes of large intensities. In fact the existence of intense electron fluxes made the previous series of experiments impossible. Energy fluxes of more than 4×10^3 erg per sec per sq. cm per steradian were recorded.

The processing of the information gained has not yet been completed. However, the author remarked that in principle one could attempt to explain the signals observed by the irradiation of of the instruments by ions, X-rays, or electrons, if these have an energy between a few keV and some hundreds of keV. Electrons appear to be the most attractive explanation. The possibility exists that the observed phenomena arose by the acceleration of the electrons in the outer atmosphere by variable magnetic fields.

Explorer Measurements

The American satellites Explorer I and Explorer III also encountered an intense flux of electrons. A. R. Hibbs in a paper, "Scientific Results from the Explorer Satellites," stated that at altitudes above approximately 1,000 km, for regions between 30° north latitude and 30° south latitude, there is an intense field of electrons with energies varying from about 50 to 90 keV. On impact with the satellite shell, the electrons produce X-ray radiation with a counting rate about 1,000 times greater than that which would be observed from primary cosmic radiation alone.

From the readings obtained, the author suggests that a large field of electrons exists around the earth more or less trapped by the earth's magnetic field. As the electrons spiral around a line of magnetic flux they descend towards the surface near the poles. There, by interaction with the atmosphere they give up their energy. It is possible that if this field of electrons exists it exists only in the region of the earth, or rather the earth's magnetic field. The sea of electrons is then being constantly drained at the bottom through interactions with the atmosphere and refilled at the top by sporadic bursts from the sun. However, it is equally possible that the "sea" extends throughout the solar system with a density that falls off only as the distance from the sun.

There are obvious biological implications in the results. The radiation field inside the Explorer satellites corresponds to about 60 milliroentgens per hour. The maximum safe dose for human beings is about 100 milliroentgens per week. Clearly, if a man-carrying vehicle were to make any prolonged flight through this environment, adequate shielding would have to be provided. If the radiation were of the type suggested by the author, a lead shield about 1 mm thick would reduce the radiation dosage by a factor of 10.

The discovery of the radiation being of considerable importance, the next American satellite was designed to investigate the phenomenon more closely. To permit the maximum exploitation of the relatively small carrier, the micrometeorite and temperature experiments carried in Explorers I and III were eleminated. Even the tape recorder in Explorer III, which permitted the storage of information gathered throughout the orbit for release in toto at a single receiving station was removed. Weight reductions in the upper two stages of the Jupiter C, combined with the use of more powerful propellents, permitted an addition of 7 lb of instrumentation, bringing the total weight of instruments to 18·6 lb.

The instrumentation in Explorer IV is designed to break down the radiation counts into levels of intensity. In a paper "Radiation Measurements from Explorer IV," by J. V. Allen, C. McIlwain, and G. Ludwig, brief details are given of the data received from the satellite during its first two weeks in orbit. The earlier results from the first satellites are being confirmed. Separation of altitude effects from latitude effects, however, cannot properly be done until the perigee has moved to the equator from its present position in the northern latitudes. The first two weeks indicate an increasing intensity with altitude at all latitudes with no indication of a levelling off.

The detectors consist of two small Geiger counters and two scintillation counters. Both scintillation counters have been found to exhibit rapid variations due to the changing aspect of the satellite. At high latitudes often more than 80 per cent of the radiation comes from one hemisphere. The flux of particles with ranges greater than 1 gram per sq. cm has now been measured as approximately 3,000 per sec per sq. cm per steradian at an altitude of 1,900 km above the magnetic equator. At least 60 per cent of these particles can also penetrate 2·5 grams per sq. cm. In addition to the highly penetrating particles there is a still higher flux of less penetrating particles, which greatly predominate at high latitudes. There the flux of particles with a range greater than 0·14 grams per sq. cm at 2,200 km is about 100,000 per sec per sq. cm per steradian, with a total energy flux of particles with range greater than 1 milligram per sq. cm of about 20 ergs per sec per sq. cm.

BLACK KNIGHT

The Black Knight is a liquid fuelled rocket with a length of 35 ft and a diameter of 3 ft. On its first firing it rose to a height of 300 miles and the nose cone landed at a point approximately 50 miles from the launching pad. The rocket is intended for general research on the problems of the re-entry of bodies into the earth's atmosphere.

Four rocket motors are housed in the lower part of the vehicle, shown in the accompanying illustration, and steering is by adjustment of the angle of the jet exhausts. The pods on two of the fins are used to carry telemetry equipment and flares. Holes in the lower part of the main structure allow access to the motors, for adjustment purposes. The rocket is fuelled from the lower end. Above the rocket motors extend the integral fuel tanks: the oxygen tank extends to just below the termination of the service stringers visible in the illustration, and the fuel tank extends above this to the base of the instrument compartment. From the latter project various aerials. The type of fuel has not been disclosed, or details of the nose-cone construction.

Gravitational Coefficients

An important application envisaged for artificial satellites was the determination of the earth's gravitational field to a greater accuracy than had previously been achieved. In a paper "Techniques of Analysing Terrestrial Radio and Optical Observations of Earth Satellites," R. H. Merson points out that calculations carried out at the Royal Aircraft Establishment, Farnborough, indicate the possibility of improving the accepted values for the coefficients in the formula for the earth's gravitational potential field. A table of orbital elements of the second Russian satellite is included in the paper and a comparison is made between the theoretical and observed values of the rate of rotation of the orbital plane. These differ by 0·7 per cent. The discrepancy may, in fact be due to the effect of atmospheric forces and this is being investigated.

Micrometeorites

Sputnik III was equipped with a ballistic piezo-indicator made of ammonium phosphate. This made it possible to measure particles with a mass of 10^{-9} gram and larger. The data obtained are still being processed but the initial results confirm the ones previously obtained from rocket investigations. These, stated Mr. Krassovsky, had indicated 50 micrometeorites per sq. m per sec at altitudes between 150 and 300 km.

Explorer I contained two devices for the measurement of micrometeorite activity. The first was a microphone mounted against the outer skin of the satellite, the second consisted of a set of wire gauges. In the data so far reduced, 38 impacts have been observed from the microphone. This would indicate an average flux of particles four microns or larger in diameter of about 10^{-2} per sq. m per sec, averaged over a time period from 31 January to 12 February. No more than one of the wire gauges was broken during the lifetime of the telemetering system on Explorer I, and it is possible that none was broken. This suggests that the upper limit for the influx of particles 10 microns or more in diameter is 10^{-3} particles per sq. m per sec, between 31 January and 14 April.

Special Article

PEACEFUL USES OF ATOMIC ENERGY

Summary of the Geneva Conference

By

Sir John Cockcroft,

O.M., F.R.S.

In his evening lecture to the Second International Conference on the Peaceful Uses of Atomic Energy, Sir John Cockcroft surveyed the work of the Conference, drawing attention to those items which he considered to be of special importance. The lecture, which was delivered on 12 September, is reprinted below in full, apart from two sections: on biology and particle physics. It serves as an introduction to a series of reports surveying selected areas of the Conference, which are being prepared for ENGINEERING by specialists in these fields. These are listed in a note on page 374.

I have been given the difficult task of surveying the work of this Conference, and using the wealth of new information, to look once again into the crystal ball and try to predict the course of peaceful development of atomic energy in the world. If we take as a yardstick the rapid progress during the last three years, I am sure you will not expect me to claim any great clarity of vision beyond the next five years.

The three years since the previous conference have been notable for the coming into operation of the world's first large-scale nuclear power stations at Calder Hall, Shippingport and recently in Siberia. This has been of great importance since we have thereby begun to acquire practical operating experience of nuclear power. This has provided us with experience on the operating characteristics of such stations, and much new information about their technology is being obtained to supplement the earlier small-scale experiments in research reactors.

Our first impressions have been that these nuclear power stations have been docile and well behaved. They can generate electricity for months on end until some minor fault develops. The most usual faults have been the faults of conventional components which require the normal amount of maintenance. There has been a surprisingly small number of defective fuel elements. Fuel elements rely on their sheathing to prevent corrosion of the fissile material by the coolant, which can then lead to leakage of radioactive fission products into the coolant stream. So a very high degree of integrity of the fuel elements is required.

The operators have reported good experience over the first two years of operation, with failure rates of only three or four per year in 10,000 fuel elements. Reactors using metallic fuel expect to achieve a burnup of at least 3,000 MW days per ton, so that one ton of uranium will do the work of 10,000 tons of coal. Reactors using uranium oxide fuel expect over three times longer burnup (10,000 MW days per ton), and indeed good irradiation stability of small samples has been reported up to 25,000 MW days per ton. Our experience of burnup of full scale fuel elements is now nearly half-way towards the target. Accelerated experience will be gained in future by increasing the enrichment of the fuel. A continuing large technological effort will need to be devoted to these problems.

The nuclear power stations so far built in the world have been either dual-purpose power stations or demonstration power stations, and would not be economic as commercial power stations. Nevertheless the experience of their operation has been invaluable in preparing the way for the next generation, which in most cases will be fully commercial nuclear power stations with credits for plutonium based on its real value for civil purposes.

Three main types of second generation full-scale power stations have been described to us; first, the graphite-moderated gas-cooled reactors; second, the pressurised and boiling water reactors, and third, the heavy-water moderated reactors. The capital costs per kilowatt of the first of the commercial nuclear power stations have been very much reduced below those of Calder Hall and Shippingport, but are still over twice those of coal or oil fired stations. The papers presented to the Conference show, however, that capital costs are likely to continue to fall appreciably during the next decade. The capital costs of United Kingdom nuclear power stations will fall a further 20 per cent by 1962 as the output goes up from 300 MW to 500 MW and a further fall of at least 10 per cent by straightforward engineering developments and increase of output is forecast in a United Kingdom paper.

The boiling-water reactor power stations seem to be growing in favour as a result of the good performance of the reactor experiments. Because of their low system pressure and small size and comparative simplicity, they may achieve very low capital costs in the next five years.

Fuel costs are the second important component of overall costs, and range from 20 per cent to 40 per cent of the unit cost, depending on whether natural uranium or near-natural uranium or more highly enriched fuel is used. The graphite-moderated and heavy-water moderated reactors will have the lowest fuel costs. Nuclear fuel costs for gas-cooled graphite-moderated reactors have been given to us as about 2 mils. The Canadians believe that for heavy-water reactors they can be brought down to 1 mil. Fuel costs for light-water moderated reactors have been reported to be about 3 mils. These are to be compared with conventional fuel costs ranging from about 3·3 mils in low fuel cost areas in the United States to 8 mils in European countries using imported coal. So nuclear fuel costs should in all cases be lower than conventional fuel costs.

The overall economy of nuclear power stations depends greatly on the capital charges, the load factor and fuel costs in a particular country. High load factors are essential to counteract the present high capital costs. A United Kingdom Electricity Authority lecturer has told us that the first group of nuclear power station could run continuously if there were no technical reason preventing this. The economic forecasts have, however, adopted the conservative figure of a 75 per cent load factor. On this assumption the 500 MW power station to be completed in 1962 is forecast to achieve parity with coal-fired stations in areas in Britain away from coalfields. On the basis of our experience so far, these power stations seem likely to achieve an appreciably higher load factor, while fuel costs are likely to fall as burnup increases with the development of our technology and as uranium prices fall, so forecasts may be conservative.

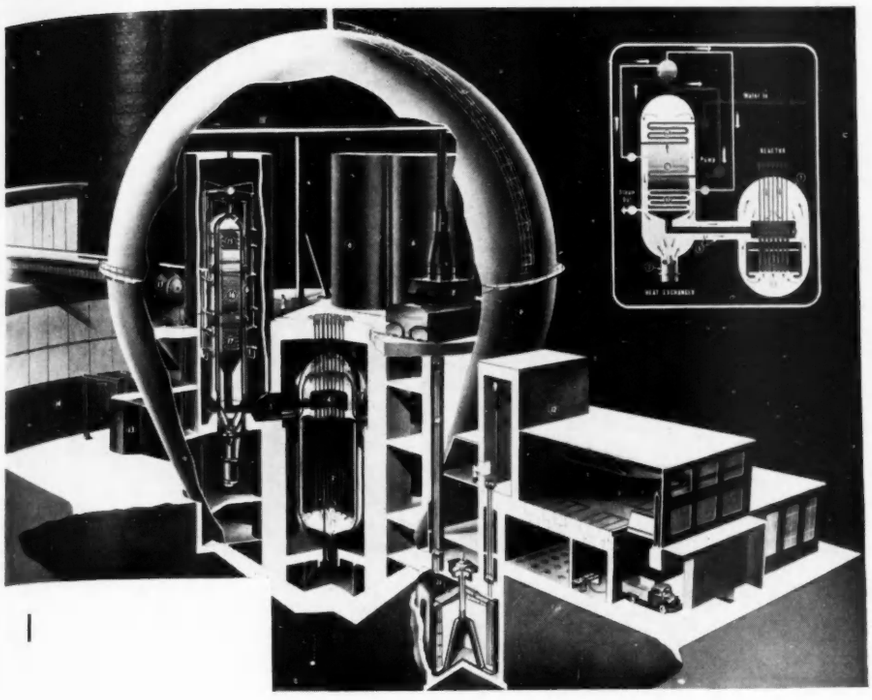
By the late 1960's as the installed capacity of nuclear power stations grows, the available load factor will fall. By that time, however, this is likely to be more than compensated by further reduction of capital costs of the order of 20 to 30 per cent, resulting from higher temperatures of operation and higher ratings associated with a switch to ceramic fuels. Nuclear power costs in Britain are therefore forecast to fall well below conventional costs by the late 1960's.

The date of achieving parity will be later in countries such as the United States where hydroelectric stations and stations using low-cost coal or natural gas can generate power at 4 mils. We have been told that stations started in the United States in the late 1960's should achieve parity.

In Italy, the World Bank study for the SENN nuclear power station has shown that with the assumed 14 per cent capital charges, nuclear power would be about 10 per cent more costly than power from oil, and that there is little economic difference between the various types. India has reported that the first 150 MW power station to be built in India could achieve parity. We see, therefore, that the date for achieving parity ranges from 1963 to 1973, depending on the circumstances of individual countries. This date will determine the rate at which large-scale installations of nuclear power stations will develop. OEEC predict that Western Europe will have an installed nuclear capacity of 10,000 MW by 1965. The United States has predicted 1,300 MW by 1963, and the USSR 2,000 MW by the early 1960's. All of this might add up to an installation of about 15,000 MW between 1965 and 1970. There is general agreement that by 1975 most new power stations will be nuclear.

Dr. Bhabha, in his evening discourse, has dealt with the need for atomic energy in underdeveloped countries, taking as his definition countries where *per capita* income is low. Since India comes very low in the table of *per capita* income, it comes in this category. Indian power requirements are doubling every six or seven years, and Dr. Bhabha considers that nuclear power stations would be competitive now and may have an installed capacity of 500 MW by 1965. Japan seems to be in a similar situation and predicts 750 MW by 1965. The growth of nuclear power in other underdeveloped countries will depend on their indigenous fuel supplies and on the available loads, and on their state of technological development. It will be hard for nuclear power to compete with diesel power where power requirements are less than 30 MW, and load factors are low. It should be remembered that technicians are scarcer than graduates in many countries, and they are crucial to this development. I agree with our president that nuclear power will not perform miracles in underdeveloped countries.

Continued on page 374



1

THREE BRITISH GAS-COOLED REACTORS OF THE FUTURE

1 *Advanced Gas-Cooled Reactor*

1. Reactor vessel
2. Cool gas entering core
3. Fuel elements in core
4. Hot gas leaving reactor
5. Ducting
6. Heat exchangers (four)
7. Carbon dioxide circulator
8. Refuelling machine
9. Containment building
10. Fuel access tube through containment building
11. Carousel
12. Fuel element building
13. Air locks
14. Control room and turbine hall
15. Economiser bank
16. Evaporator bank
17. Superheater bank

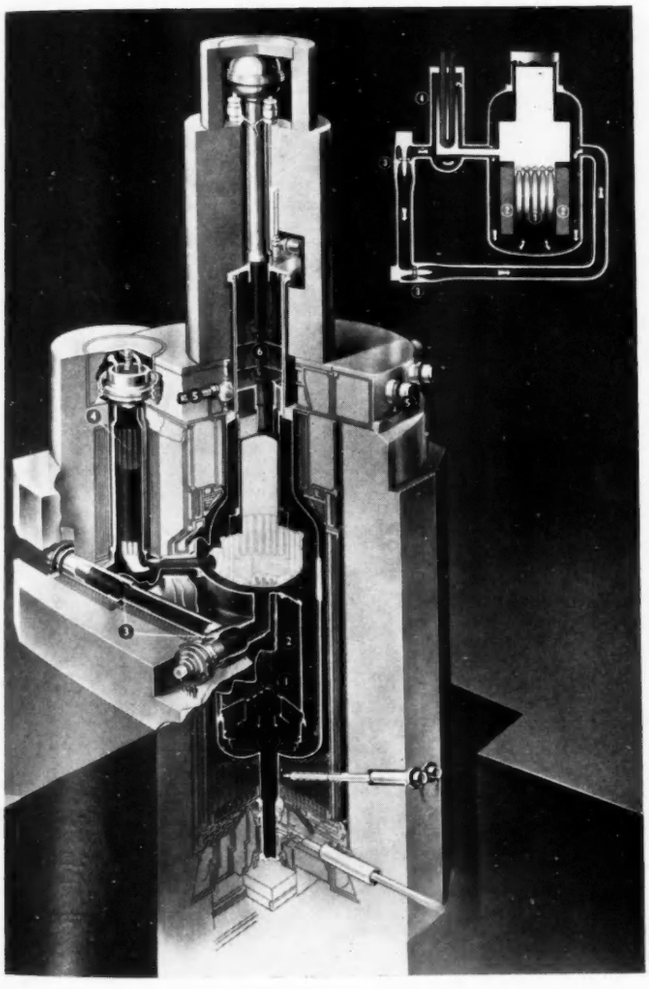
2 *High-Temperature Gas-Cooled Reactor*

1. Core
2. Reflector
3. Primary-coolant circulators
4. Heat exchanger
5. Control mechanism
6. Charge-discharge machines

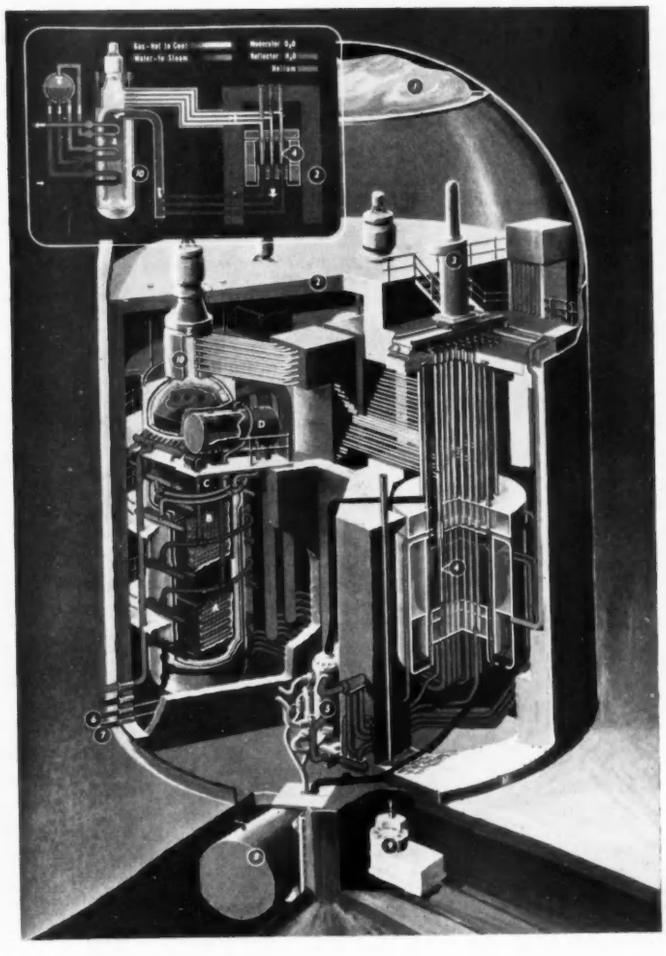
3 *Gas-Cooled Heavy-Water Moderated Reactor*

1. Helium gas storage
2. Biological shielding
3. Charge machine
4. Fuel element
5. Moderator and shield cooler
6. Cooling-water inlet
7. Cooling-water outlet
8. Heavy-water storage tank
9. Fuel-handling machine
10. Steam generator
    - *a*. Economiser
    - *b*. Evaporator
    - *c*. Superheater
    - *d*. Steam drum
    - *e*. Gas circulator

2



3



Continuing Summary of the Geneva Conference

By the late 1960's new, third generation, types of stations may be coming into service. We have had reports of operational experience with their precursors, the reactor experiments. The organic-liquid moderated reactor experiment has shown that it is likely to be a simple reactor to operate because of its low system pressure and its non-corrosive, non-radioactive coolant. The previously unknown cost of replacement of the moderator required by radiation breakdowns seems to be about one mil per kWh. The Oak Ridge experience on the aqueous homogeneous reactor shows good progress in overcoming the difficult compatibility problems, but the stability of the fluid fuel is still a crucial point. The sodium graphite reactor experiment will provide important information on sodium technology and on metallic fuel elements operating at high temperatures. The high-temperature gas-cooled reactor projects using all-ceramic fuels may well be important for propulsion as well as for land use by the end of the 1960's. A high-temperature gas-cooled reactor experiment seems likely to be built in Britain as a collaborative European joint project.

Fuel Cycles

We have heard a number of interesting papers on fuel cycles. It seems clear that with the general trend towards the use of uranium oxide fuels, most reactors built after 1965 with the possible exception of the heavy-water reactors, will require some enrichment. The graphite-moderated reactors will require only modest enrichment of the order of 1 per cent uranium 235. The light-water moderated reactors will require enrichment ranging up to 3 per cent uranium 235.

The enrichment can be provided either by uranium 235 from diffusion plants or by using plutonium from earlier reactors. Thereafter they could operate on a natural or slightly enriched uranium feed by recyling plutonium, using this in the form of oxide mixed with uranium oxide. We have heard of promising technological work on recycling and of the limitations imposed by the accumulation of higher isotopes, such as plutonium 242. One of our speakers has predicted that by the time nuclear energy is producing 20 per cent of world power, we should need to invest about 5 per cent of the capital for nuclear power programmes in diffusion plants to provide the initial charges of uranium of low enrichment.

An alternative fuel cycle is to feed the plutonium to reactors of the fast breeder type which will have a positive gain factor for plutonium. The advantage of this would be that in the long term we should achieve a much better utilisation of world uranium supplies. The superabundance of uranium which is forecast for the next two decades has shown that this is not an urgent problem. We can therefore take time to develop the difficult technology of fast reactors in a thorough manner. We have heard reports in this Conference on the results obtained with experimental fast reactors; from their operation we have gained a great deal of knowledge about the reactor physics, kinetics and stability of these reactors, which has been important in the design of the higher power reactor experiments which will come into commission during the next two years. Already, however, prototype fast reactor power stations of 50 to 200 MW electrical output are being constructed and designed. The rate of installation of fast reactors will depend first on our experience with the reactor experiments, and second on the rate at which plutonium becomes available from thermal reactors. Fast reactors are unlikely to contribute much to world power before the 1970's.

Thorium possesses considerable advantages as a fuel for thermal reactors, but a large investment of uranium 235 or plutonium is required to start the thorium cycle. We have had a description of the Indian Point 275 MW (E) nuclear power station, the first full-scale reactor which will use the thorium cycle. Thorium may well be coming into use by the late 1960's, especially since large supplies will be available as a by-product of uranium mining.

Uranium and Thorium Supplies

We have heard from Mr. Jesse Johnson that his 1955 forecast of uranium and thorium supplies have been more than realised. He has told us that on the basis of current production costs we could obtain supplies of at least 40,000 tons a year of uranium oxide at prices of between 8 and 10 dol a pound. The ore reserves in South Africa, Canada, the United States and France are likely to contain at least 2 million tons of uranium, and on the basis of present geological data and the experience of the last ten years, an additional 2 million tons is likely to be available. These forecasts are two to four times higher than those made in 1955. If we guess that reserves in USSR, China, and other countries are of the same order, the world reserves of high grade ore are likely to be of the order of 10 million tons of uranium. The supplies of uranium in lower concentrations in shales and phosphorites are said to be unlimited. We have also heard that in addition to deposits of thorium in India, important deposits of thorium have been found in Canada at Blind River, where the ore contains one part of thorium to two parts of uranium oxide. World thorium reserves seem likely to be at least 500,000 tons.

At 30 per cent burnup, which might be achieved by breeding, 10 million tons of uranium is equivalent to 10^{13} tons of coal, which is three times the world's estimated coal reserves. We are likely to have developed fusion power long before we run out of uranium.

Nuclear Propulsion of Shipping

The technical feasibility of the nuclear propulsion of shipping has been abundantly demonstrated by the voyages of the United States submarine Nautilus, culminating in the remarkable voyage underneath the polar ice cap. The pressurised-water reactor used to develop steam for its propulsion has proved to be highly reliable. We have heard of the first approaches to commercial nuclear propulsion. The US Savannah, a combined passenger-cargo ship coming into commission in 1960, will use a pressurised-water reactor developing 22,000 shaft horse-power. The pressurised-water propulsion unit seems likely to achieve fuel costs based on United States prices about equal to those for oil fuel. Present capital costs are, however, three to four times higher than conventional capital costs, and a drastic reduction of these costs is necessary before parity with conventional propulsion is achieved. The United States expects to build a nuclear tanker using a boiling-water reactor for propulsion by 1962. Since this type of reactor appears to have lower capital costs than the PWR this should help to bridge the gap, though operating costs will still be well above conventional costs. It seems likely that we will have to wait five years or more before we will know whether truly commercial nuclear propulsion is a feasibility. However, there is one immediate application which would be impossible without nuclear power. The opening up of the 6,000 mile seaway north of Russia has had to wait for the practically unlimited endurance of the nuclear propulsion unit, and we have heard details of the icebreaker Lenin, which is due to be commissioned in 1959. Three pressurised-water reactors will provide 44,000 shaft horse power for propulsion.

In contrast with the hopeful outlook for marine applications, commercial nuclear aircraft propulsion seems much further away.

Fusion Reactors

In his presidential address to the last conference, Dr. Bhabha said that he predicted that a method would be found for liberating nuclear fusion energy in a controlled manner within the next two decades. The papers presented to this Conference on fusion research have shown that remarkable progress is being made in this field on a very broad front. Most workers have in view the long-term objective of attaining "temperatures" of 50 to 100 million degrees in a mixture of deuterium and tritium gas. This should enable the "break-even point" to be reached at which the energy release from fusion reactions in a mixture of deuterium and tritium gas would equal the energy input. The long-term goal is to go well beyond the 100 million degrees, to use the deuteron-deuteron reaction and eliminate the dependence on lithium as a source material for tritium.

Although we have been using the word "temperature" as a measure of our progress, we should remember that it is not strictly applicable to these very complex hot plasmas. We have also to remember that the electron temperatures are often very different from the deuteron temperatures, and it is the latter which are important for our objective.

We have had reports from several laboratories and "temperatures" up to several million degrees have already been achieved in deuterium gas, with prospects of going considerably beyond this in the future. It is necessary, of course, to be able to hold these high temperatures for a sufficiently long time for an appreciably proportion of the deuterium to be burnt. Thus at a temperature of 50 million degrees in a deuterium-tritium mixture and with gas densities of about one-thousandth of an atmosphere, only 1 per cent of the deuterium would be fused in a tenth of a second.

The containment of this high-temperature gas depends in all cases on the use of magnetic fields, the so-called "magnetic bottle." The containment also depends on being able to maintain this hot, tenuous plasma, generating and radiating energy at a great rate, in a stable configuration not subject to violent oscillations or eruptive processes leading to loss of energy.

Two main lines of attack on the fusion reactor have been described to us. The first is the pinched high-current discharge method, used in the ZETA and other tori, the Stellarator and the straight discharge tubes. The stability of the plasma depends critically on the relation between

Geneva Conference Reports

Surveys of subjects covered at the Second International Conference on the Peaceful Uses of Atomic Energy, at Geneva, have been undertaken for ENGINEERING by the following authors.

Power Reactors ..	Mr. G. W. K. Ford, Research Manager, Dounreay
Research Reactors..	Dr. V. S. Crocker, Reactor Division, Harwell
Thermonuclear Research	
(Pinch Effect) ..	Dr. A. A. Ware, (AEI)
(Other Devices) ..	Dr. R. J. Bickerton, Controlled Thermonuclear Research Division, Harwell
Propulsion	Mr. B. T. Price, Reactor Division, Harwell
Shielding and Safety	
Engineering ..	Mr. R. P. Kinsey, Chief Engineer, Advanced Reactor Design Office, Risley
Metallurgy	Mr. L. M. Wyatt, Technical Manager, Central Technical Services, Research and Development Division, Risley
Instrumentation ..	Mr. R. B. Stephens, (Mullard)
Physics and Accelerators	Dr. M. J. Poole, Group Leader, Neutron Physics, Nuclear Physics Division, Harwell
	Dr. M. Sowerby, Nuclear Physics Division, Harwell
Applications of Radioisotopes	Mr. E. R. Wiblin, Isotope Division, Harwell
Isotope Separation..	Dr. H. Kronberger, Director, Research and Development, Risley
Chemistry and Processing	Dr. R. Hurst, Director, Dounreay

the magnetic fields produced by the circulating current and the additional magnetic fields applied to produce containment and stability. In ZETA, containment is not well understood and we do not yet know how far we will be able to maintain containment as energy input is increased. We have heard that other torus devices can lose large amounts of energy by runaway electrons escaping to the walls of the tube, and that the production of a quiescent plasma is the crucial problem.

In the torus devices the plasma is heated in various ways: by resistive heating; by shock-wave heating; or by radiofrequency methods. "Temperatures" have so far been measured by Doppler broadening of highly ionised impurity atoms or by even more indirect methods. It seems that deuteron temperatures of several millions of degrees may have been reached but that electron temperatues are much lower.

The second class of fusion device known as the "mirror machine" also contains the plasma in a magnetic bottle but the plasma is heated in a different way. In the Pyrotron, the first of the mirror machines, the plasma has been heated by using pulsating magnetic fields acting like magnetic pistons—to compress the plasma, and electron temperatures of about 10 million degrees have been reported. In the Oak Ridge DCX machine a plasma is formed by passing intense beams of high-velocity molecular ions into a chamber where the molecules pass through a powerful carbon arc and are split up into neutral and charged hydrogen atoms. The neutral atoms leave the plasma and the charged atoms are trapped in the magnetic bottle and form a hot plasma. The progress of this method will depend critically on producing several amperes of molecular ions and on keeping the loss of energy from the plasma low; the method will be watched with great interest. The USSR OGRA machine which has just been completed will work on a similar principle, but the molecular ions are to be split up by impact with the atoms already there in the course of a long spiral path to and fro between the magnetic mirrors. These mirror machines also will depend for their success on being able to maintain a quiescent plasma.

Fusion reactors will aim ultimately at developing several hundred megawatts per cubic metre of plasma, so that they may not be very different in size from fission reactors. It is too early to judge the relative prospects of the different approaches to fusion power demonstrated so well in the scientific exhibition associated with the Conference—so much depends on experiments still to be carried out. Although neutrons emitted after the fusion of deuterium nuclei have been observed from many of the devices, the deuterons responsible have so far been mainly speeded up by direct processes. No laboratory has so far claimed what have been called "true thermonuclear reactions" though we are probably not far away from this. However, I agree with Academician Artsimovich that this is not the important question. The origin of the neutrons will become clear enough if we can increase the temperatures in our plasmas. The important question is whether we can maintain stability in our plasmas as we feed in more and more energy, and whether we can, in due course, reach the break-even point where the energy generated by fusion equals the energy input. Dr. Thonemann thinks this may well take ten years, and that even if we are successful it is likely to take at least another ten years before we know whether an economic fusion power station is practicable. I agree with this. Dr. Teller's timescale is even longer.

Health and Safety

A number of lecturers have discussed the problems of reactor safety. We have had reports on the important experimental work on the kinetics and stability of reactors. We have learnt about the effects on reactor kinetics of the accumulation of radioxenon, the formation of steam voids and the growth of plutonium in fuel. These will not produce any difficulties in operation provided the reactor instrumentation is adequate.

We have also learnt a great deal from three reactor accidents which have led to partial melt out of the reactor fuel elements. Although two of the reactors were put out of commission for a year and one was written off, no one was hurt by these accidents or received an overdose of radiation. The results of the accidents agree in a remarkable way with one of the experimental papers in showing that only a very small fraction of some of the bone-seeking isotopes escaped from the melted fuel. The disturbances due to these accidents were accordingly less than envisaged in the 1955 papers. Later generations of reactors than these early models are much better protected by containment and instrumentation, and some papers have shown considerable progress in advanced designs of containment which are thought to be proof against the maximum credible accident. This gives us considerable confidence in safe operations in the future, and we may, in due course, expect the location of plants in more populated areas.

We have also heard of the growth of national reactor safety and inspection organisations, analogous to those in being for the aircraft industry. They inspect designs and prescribe codes of operation to help to maintain safety. We may also need an International Reactor Safety Panel to help smaller countries who do not have safety experts available to them. In our legal sessions we heard that new international conventions may be required to deal with problems raised by mobile reactors, the disposal of radioactive effluents in the oceans, and any possible damages beyond national boundaries from reactor accidents.

Industrial and Research Uses of Isotopes

The multitudinous industrial uses of radio-isotopes continue to increase rapidly. Dr. Libby has estimated that their use in process control, in the oil industry and other production fields, is already saving United States industry 400 million dollars a year and that the savings will soon reach the multi-billion dollar level. Academician Topchiev has reported that the present annual savings to Soviet industry by their use amount to over a thousand million roubles. Several million metres of oil-well bores have been logged by neutron sources.

Sources of radiocobalt and of radiocaesium are shortly becoming available in strengths of the order of 100,000 curies, for industrial applications. These powerful sources will be used for sterilisation of hospital dressings, pharmaceutical products and other materials where chemical sterilisation is less attractive. They can be used to produce grafted polymers in which the properties of the original polymer are beneficially changed. Thus Dr. Libby told us that a styrene-polyethylene film had been used to make an ion exchange membrane which had much improved properties for purifying brackish water. Dr. Topchiev has reported the production of block polymers of polyethylene and polystyrene which have high strength and stability up to 250° C. Many more chemical applications are promising, and we are likely to make full use of the tens of millions of curies of radiocaesium and radiocobalt which could become available as by-products of the power programme.

The movement of silt in river estuaries and harbours is now being studied with the help of radioactive tracers in many parts of the world, following pioneering studies in the Thames estuary. Gold and tritium-labelled water is being used to determine the flow of water in rivers, sewers and underground strata. This may have important applications to the survey of water resources in underdeveloped areas, and for the control of irrigation in arid areas.

The polonium alpha-particle camera is an example of a new research tool which will make it possible to measure mass differences of 10^{-13} and possibly 10^{-15} grams in microtome sections of biological material. These examples of the industrial and research uses of isotopes, taken almost at random from an enormous field, can do no more than illustrate their already great and growing importance.

Atomic Review

Notes and News

Turbines for the AGR

An order for turbine plant for the United Kingdom Atomic Energy Authority's new advanced gas-cooled reactor (AGR) has been placed with the English Electric Company Limited. The contract is for a 33 MW steam turbo-alternator set and condensing and feed heating plants with auxiliary equipment. Work on this reactor began this year and it should be in operation by 1961. The purpose of the reactor is to assist the Authority during the 1960s to realise the maximum development potentialities of the gas-cooled graphite-moderated reactor. The turbine is of the two-cylinder impulse reaction type rated at 33,000 kW and operating at a speed of 3,000 r.p.m. with steam at 650 lb per sq. in (g), and a temperature of 850° F. The alternator will be air-cooled.

ICI To Build Beryllium Plant

Imperial Chemical Industries Limited, Metals Division, is to establish the first plant in Europe for the production of wrought beryllium. The plant is designed to produce semi-fabricated forms of the metal, such as rod, tube and plate, and finished machined parts. Its first task will be the execution of a production scale contract placed with ICI by the United Kingdom Atomic Energy Authority (Industrial Group) as part of a nuclear development project. Subsequent spare capacity may find additional outlets for this unusual metal.

Interest in beryllium as a nuclear engineering material has been intensified by the need for a metal which will perform satisfactorily in the higher operating temperatures envisaged in gas-cooled reactors. For the present programme of British reactors, operating at temperatures up to about 470° C, special magnesium alloy materials are used for sheathing the nuclear fuel. For the higher temperatures needed to obtain increased thermal efficiency, materials with greater strength at these temperatures must be used and the most promising of these is beryllium. This metal, which has a melting point of 1,280° C, is light in weight, has good mechanical properties and good corrosion resistance to carbon dioxide at elevated temperatures. In addition, beryllium has by far the lowest neutron absorption cross-section of any of the possible constructional metals. For this reason, the Industrial Group intends to use beryllium fuel cans in its advanced gas-cooled reactor (AGR), in which fuel element surface temperatures as high as 600° C are planned. Some unusual features are involved in the manufacture of wrought forms of beryllium. The metal, which is received as flake or as small beads, is melted under vacuum in induction furnaces to produce an ingot. This is really a refining process: the cast ingot, having a large grain size and very poor workability, cannot be rolled or extruded directly in the same way as conventional metals are. It has to be made into fine powder which is then heated and compacted ("sintered") under vacuum to produce the various shapes required for further processing by conventional plant. It is also toxic.

EMI Hand and Clothing Monitors for UKAEA

The United Kingdom Atomic Energy Authority has placed a large order with EMI Electronics Limited for the company's new hand and clothing monitors.

The Human Element

Day and Wage

The upshot of the delegate meeting of the Confederation of Shipbuilding and Engineering Unions at York last week was a decision to go back to the employers and ask for more. The resolution finally passed had the support both of Mr. Carron, the president of the Amalgamated Engineering Union, and Mr. Hill the Boilermakers' secretary and in this way reasonableness and extremism were able to come together under the same banner.

All is not complete unanimity after the meeting however. The two general workers' unions think that there should be the same increase for both skilled and unskilled workers. The AEU is reported as being willing to take another look at the last wage offer from the employers if they will in turn make a gesture about hours of work. There is a strong body of opinion however which wants to see the wage matter cleared up first before going further into working hours.

It now rests with the meeting with the employers as to whether the issue goes to arbitration. Some trade unionists would take it there right away to save further time, but others are possibly willing to talk first to the employers since the last word from them was a hint that there might be some point in further talks. There will be a strong body of opinion among the employers who will resist anything that is going to raise costs more than the absolute minimum. In the engineering industry there are very big differences between companies' ability to pay higher wages out of profits. It is sometimes the medium and small concerns that suffer, and to be small in negotiations these days is the worst affliction of all—and the unions know it.

Posters to Promote Suggestions

Since the war a large literature has accumulated on the value of suggestion boxes. A good deal of it has been highly critical. Nevertheless, the idea has been proved workable in a large number of cases and as a management idea it refuses to be written off.

The Industrial Welfare Society has now produced a new service for industry. Armed with the knowledge that about 400 suggestion schemes are in operation in this country, and this is thought to be a growing figure, it has prepared a suggestion scheme poster series. These are to be published at regular intervals at 2*s* 6*d* each. They are screen printed in up to five colours and measure 15 in wide by 20 in deep. Six designs are now available and new ones will be published each quarter in groups of three, starting in January 1959.

It will be interesting to see whether posters of this kind make an impression. They will be supplementary to or a substitute for the advertising material which concerns are now using. Their success depends on there being a general visual appeal in a poster dealing with a subject of this kind. In that sense they are in a way unique in the field of visual persuasion. They divorce reaction to an idea entirely from local tradition and locally prepared material. This worked in wartime when there was a national crisis. There may soon be a chance to see if it works in an entirely different kind of industrial atmosphere.

Ductile Copper

The threat by white workers in the copper mines of Northern Rhodesia to strike if they do not get agreement with the copper companies on redundancy is a classic example of the importance of timing demands for improved wages or working conditions. The Government may now be forced to intervene. Although the dispute is about redundancy, the real issues are the fall in earnings for all copper miners since the world price of copper fell over the last two years from over £400 a ton to a "low" this year of about £165. There are also long-standing problems still to be solved about demarcation of skilled and unskilled work.

The white union has decided to fight the issue now. It would appear that the decision to do so is either too late or too soon. The companies can afford to face the consequences of a strike at present with the price of copper rising only slowly (being now almost £210 a ton). Anything which makes copper temporarily scarce as the United States comes out of its depression is bound to help the trend of prices.

Beyond the immediate tactical issue, however, is the need to work out some arrangement between management and organised labour about wage rates and bonuses in an industry which has to face extreme fluctuations in prices. Neither management nor labour can negotiate sensibly for long if both sides seek only short-term solutions in an industry selling a product which can swing in less than two years between such extremes in price.

Deviation in Moscow

A flurry of criticism and second thoughts at the Foreign Office has caused the post of Scientific Attaché at Moscow to be up-graded. By ordinary standards the change from a Principal Scientific Officer to a Senior Principal Scientific Officer may appear a grudging gesture, but for those versed in protocol and the way embassies have to work there may be a world of difference.

If Scandinavia rates a peripatetic Scientific Attaché then Russia merits a static one. Beyond that, two issues must not be overlooked in the finer points of Civil Service rank. The ability of the man, irrespective of his seniority, matters enormously, for these positions can be either easy going sinecures or posts of great significance depending how conscientious the incumbent may be. Secondly, much depends on what happens to the material he produces from his desk. The heart-breaking lot of most attachés who work with vigour and imagination is that their reports are rarely read by the man who can make most use of them. This may be less true of Moscow for it is a sensitive point in this country's foreign relations but even there it has to be emphasised that there is much more to the work than being in possession of the right rank to speak directly to the right opposite number in other embassies and at the Kremlin.

Plastics Invitation

The plastics industry is the latest one to produce a booklet on careers. This one, called *Careers in Plastics*, begins with an outline of the industry and an indication of its progress in recent years. This is well worth saying in this case for the rate of growth has been phenomenal even in the last ten years. There follows a list with explanations of the various stages of production.

Sections dealing with entry and training are kept short and little use is made of visual material. It is a matter of opinion whether pictures of large buildings and complicated machinery really appeal to youngsters looking for a career. Text and tables, as in this case, probably make a bigger impression on thoughtful parents and it is such parents who produce good candidates for jobs. Some details are also given of educational requirements and the apprenticeship scheme.

As the bulge becomes available for employment the task of companies for the next few years will be, not the recruiting of large numbers, but enrolling the right kind of applicant. A greater degree of discrimination is going to be forced on all industries and those who can bring together good recruitment literature with a sound appraisal of candidates' technical potential will have made a considerable achievement.

Drift into Jobs

When so much is being done to canalise school-leavers into the right kind of job it is as well to remind ourselves from time to time of the apathy and ignorance on the subject among those who from choice or background will never get much beyond semi-skilled work. It is also important to recognise that middle-class attitudes on careers are not universal. An article "Factors Affecting Choice of Job Among School Leavers" by Miss Sheila Mitchell in the latest issue of *Personnel Management* puts the situation in perspective.

In a small Yorkshire town all young people born between 1 September 1936 and 31 August 1939 were interviewed. On a list of questions on a card most boys put importance of training facilities high in saying what sort of a job they wanted. Girls tended to go for immediate gains —naturally since their marriage age averages 18 to 19 among secondary modern school leavers in that area. But these were in a sense leading questions. On questions about parental choice and influence the answers were less reassuring. Few parents seemed to have any preferences about jobs for their children—especially fathers for daughters. Mothers advised daughters to keep off work that was dirty, distant or poor in social status. Fathers told sons to go for a trade.

Overall, however, the influence of parents, school teachers or other advisers (not very thick on the ground in this locality it is true) was slight. Ignorance and drift are still major factors to be taken into account in directing the young.

Handling the Visitor

Developing techniques for looking after the visitor, whether he be the managing director from a large customer or an unskilled operator applying for a job, is part of the human relations problem for all organisations. All offices and factories to-day have a larger flow of visitors than they had before the last war and the general public in a vague sort of way is more conscious of industry and commerce. A booklet on how to deal with visitors has been issued by the Industrial Welfare Society called *Appointment at 10.30*, by Miss Winifred McCoullough.

The booklet deals with ways of welcoming different types of visitors and serves the useful purpose of emphasising that a good human relations job can be done by giving thought and consideration to the subject. Like all of its kind it may slightly overdo the story and in an effort to have its say in an interesting way it becomes a little easy in its style. Nevertheless, it is all part of the useful effort to take the barbarism out of business.

A good technique for dealing with different kinds of visitors is really a branch of office administration. A concern which is slovenly with all visitors who have not come expressly to see one of the directors or the general manager is likely to be equally bad in other aspects of its administration. Most good firms manage to have the right kind of receptionist who is there to say the right kind of things.

TRAINING TO UNDERSTAND PEOPLE

By Z. M. T. Tarkowski

The behaviour of people at work and their relations with their fellows are important influences on the efficiency with which a project is carried out. It is often difficult to understand human behaviour, not only because no systematic theory of behaviour has been accepted, but also because such theories as are in existence seem, to a practical man, remote from daily problems. Moreover, the word "understanding" itself raises various difficulties. This article discusses different interpretations that are put on the latter term and the confusion that can arise when they are not recognised. The author has contributed a previous series of articles to ENGINEERING *on human problems in industry,* and is at present engaged, with his colleagues, in organising a course at the Northampton College of Advanced Technology, London, on direction and supervision of engineering and scientific personnel. He has also been doing work in connection with management training for the Training and Education Division of HM Treasury, including preparation of material on human problems in the organisation of scientific research for a series of conferences on management for senior civil servants. The present and previous series of articles constitute an attempt to move by stages towards a systematic theory of human behaviour.*

Is it possible to train people to understand better others and themselves? Many are profoundly sceptical and deny such a possibility, but a few believe in it fervently; there are also those whose job it is to organise and conduct such training, some of whom are honestly perplexed about this task.

It is obviously necessary to avoid waste of time and money on fruitless pursuits, but the issue is pressing and cannot be postponed. In order to supervise people effectively it becomes increasingly necessary to understand more about such things as various types of ambition, the ways to arouse enthusiasm and to avoid apathy. It is important to know about the psychology of conversation and discussion and its bearing on interviewing, consultation, instruction-giving and the conduct of meetings.

Authoritarianism, failure to delegate and over delegation present some knotty practical problems. It is often difficult to know what to do in practice with people's argumentativeness and moodiness, their unwarranted or inflated ambition, conceit or despondency. Perfectionist trends or inclination to negligence are not easy to cope with; even more difficult to deal with are the problems created by exaggerated suspiciousness or undue jealousy.

Many eminent industrialists have been heard recently emphasising the importance of these problems. Their exhortations, however, often phrased in most general terms, for instance, to treat people as individuals, or to bring the human touch to management, are difficult to translate into practical action. Moreover, the emotional or sentimental approach which occasionally characterises these appeals, or the preaching attitude with which they are delivered, may sometimes provoke distrust among more hard-headed members of the industrial community. These matters cannot be divorced from their moral and ethical aspects, but to minimise the distrust it is also necessary to acknowledge their seriousness in purely financial terms.

Human problems range from the large-scale issues such as labour relations, collective bargaining, absenteeism and labour turnover—through the questions of recruitment, training and promotion policies—to the apparently small-scale problems of personal relations between individuals at work. The latter seem to many people to be inescapable, but at the same time of no great importance. That they may be serious, however, becomes obvious if one reminds oneself from daily experience of the irritation and disruption often caused by personal friction between colleagues, or superiors and subordinates at any level.

More particularly, feuds and rivalries between departments and divisions, and between individual members of senior and top management, may have disastrous effects on the future and fate of whole organisations. This is nothing new, but at the present time the problem has become much more acute, when decisions may involve enormous capital outlay on equipment which cannot easily be disposed of if it proves not altogether suitable. A resolution to produce a new type of product, say an aircraft, to adopt some specific method of automatic data processing, or to automate wholly or partly a factory may be almost irrevocable once the action has gone forward and the developments are under way. The completion of plans may take many years and it is extremely damaging not only financially, but—even more important—morally, if in the end they prove to be a mistake. Even if only half-way through its implementation, a project is abandoned or altered, the effect on morale—and through it on efficiency—may be quite disastrous. This danger can be avoided if the purposes of the new development are not disclosed, but such a policy has other undesirable consequences. As is well known, the employees not adequately informed about the affairs of a company become bored and indifferent and lose their initiative and drive.

Thus, top level decisions both in technical matters and in the questions relating to personnel and employee relations will have a powerful and long-standing effect for good or evil on the people of whom the organisation consists. It is therefore very important, more so than ever, that these top level decisions should be affected as little as possible by rivalry and friction between cliques and individuals. They should emerge from friendly, but outspoken and sincere, consultations between people whose communication with others is not hampered by petty grudges, trifling embarrassments and irritations, the inability to speak and to criticise frankly, or to bear such frank criticism. Fruitful and effective discussion cannot take place in an atmosphere of anxiety, servility and authoritarianism or, on the other hand, false *bonhomie*, insincere and aloof politeness or studied informality.

These points are of general application but more especially, as there is a shortage of scientific and engineering manpower and the speed of technical development is of great importance, it becomes necessary to avoid the waste of time and effort of the existing human resources through personal friction and inadequate understanding of people. The quality of the product, its competitive value and its profitability in financial terms—all these depend ultimately on various forms of industrial research; so does the efficiency of production methods and of the selling techniques. It is in the research and development departments that the long-term policies are formulated and discussed before being finally decided upon. And it is therefore especially important that the full deployment of scientific resources should not be hampered by the insufficient knowledge of human behaviour.

THEORETICAL DISCUSSION

To restate, briefly the argument, it is thus important, everywhere that people should be understood, their reactions to each other and to their work properly appraised and predicted, and their future development accurately forecast. The placement of individuals, their training and terms of reference must be carefully planned in the light of understanding their personalities, their effect on each other, their individual needs and their emotional make-up.

To anyone with technical or scientific training it will be obvious that to achieve these aims it is necessary, firstly, that an adequate theory of human behaviour should exist, and secondly, that those who direct or supervise people should be trained in its understanding and application. The present series of writings constitute an attempt to move in that direction.

In the absence of an adequate theory the notion of "understanding people" becomes elusive and vague and leads to confusion. In particular, when the topic is mentioned it is the music-while-you-work, the pandering and pampering which spring to many people's minds and the discussion is bedevilled by these associations.

In order to avoid confusion it is necessary to distinguish carefully between at least two different meanings of the phrase "understanding people." These two senses can be called the *emotional* and the *intellectual*.

If John says: "I understand George" it usually means that John sympathises with George, that he can get on with him, that he appreciates George's good points and is strongly inclined to forgive and to minimise whatever irritating or unpleasant habits George might have. It may also, but not necessarily, imply that John likes George personally and that he may even positively seek his company.

On the other hand if John says that he understands how his car engine works this seems to mean something quite different. Sympathising, appreciating good qualities, forgiving and minimising faults do not enter into it at all. Neither has personal liking or seeking the company any connection with it. The assertion "I understand how my car engine works" may mean that I know how to mend it when it is out of order or when it develops a fault. It definitely implies that if I am discussing it with a car mechanic I know what he is talking about and can ask him sensible questions. I can also appreciate and judge what sort of information he might require in order to mend my car, and I will volunteer it without him having to ask for it; if he does ask questions I can answer them intelligently.

Similarly, any statement of the form "John understands how this piece of apparatus works" (for example, a wireless set, a computer) entails all the implications given in the previous paragraph, and possibly a few more. For instance, it may involve the conclusion that John can predict how the apparatus will behave in given circumstances, such as under a change of temperature or of air pressure.

To say "John understands this piece of apparatus" is not very precise. His understanding of it may be only very slight, or it may be profound. In the latter case he will be able to predict how the performance and the characteristics of the apparatus will change with age due to wear and to conditions under which it works. He will be also able to appreciate and to judge which methods of maintenance and techniques of operation will tend to prolong the life of the machinery and maintain its efficiency, and which will have a detrimental effect on it, increase wear and tear and lead to an early breakdown. In case of extremely good understanding John might be able to utilise the machine better than anyone else has done, and he may even improve its efficiency and performance by devising new methods of handling it, not thought of before.

Furthermore, to say that John understands a piece of apparatus may mean, but does not necessarily, that he can teach others how to understand it, how to operate it and to mend it; that he may be able to talk about it in an intelligible and possibly also interesting way, and perhaps even write about it.

To repeat, the two meanings of the phrase "*A* understands *x*" can be conveniently termed the *emotional* and the *intellectual* sense. If for *x* we substitute the name of a person, a domestic animal or the title of a work of art the phrase is

* *Understanding the Behaviour of People at Work: Introductory Notes for Engineers and Executives*, by Z. M. T. Tarkowski. A series of six articles reprinted from ENGINEERING and now available from the Publisher, ENGINEERING, 36 Bedford Street, London, W.C.2, price 4s, post free.

Production

RECONDITIONING HYDRAULIC RAMS

Reconditioning of a series of rams on a Loewy 2,500 ton hydraulic extrusion press has been carried out by Reynolds T I Aluminium Limited, Redditch, with no more disturbance to the equipment than was involved in withdrawing the rams from the press. The work was done by Nicol and Andrew Limited, Hillington, Glasgow, using their patented " Master Hone " equipment.

The main ram of the press is 45 in diameter for 9 ft 4 in, stepped down to 19½ in diameter for a further 9 ft 4 in, giving an overall length of 18 ft 8 in. It weighs about 30 tons. To rectify wear which had taken place over the years it was necessary to remove 0·024 in from the 45 in diameter portion and 0·075 in from that of 19½ in diameter. It was essential that the diameters should be concentric after regrinding. Similar treatment was given to the twin main return rams, which have two working diameters, 6 in and 18 in, and an overall length of 23 ft. Here again it was essential that the two diameters should be concentric, and in this case it was also necessary for the twin rams to have identical diameters. The piercer ram, 20 in diameter and 12 ft long, was also reconditioned in the same way.

Reconditioning to close limits of hydraulic press rams is carried out on site with a Nicol and Andrew " Master Hone."

As a result of the success of the operation it has been decided to use the same method for reconditioning the ram of a 5,000 ton press. This ram is 57½ in diameter by 12 ft long, and the equipment now being produced for doing this work is the largest yet made.

Continuing Training to Understand People

usually taken in the *emotional* sense. Thus it has a connotation of emotional sympathy and possibly even liking. On the other hand if for *x* the name or description of a machine, a physiological system, a scientific theory or a mathematical theorem is substituted the phrase will be usually taken in the *intellectual* sense.

It is clear that in both cases there are *degrees* or *levels* of understanding. One may like and appreciate a person, or a work of art, more or less deeply. Equally well, the *intellectual understanding* may be very profound or very superficial and one may talk of varying *degrees*, *levels* or *depths* of understanding. Naturally enough, no numerical values can be assigned to such adjectives, nor can the depth of understanding be measured in any way. Nevertheless, it is necessary to use such phrases and adjectives when human beings are discussed although it may be dangerous to try to use them too rigidly or to attempt to make them more precise than they basically are. Thus, if a technical vacancy is to be filled it is important to consider, among other points, which one of the candidates has a better or a deeper understanding of the machinery he will have under his control.

In the example given in the last paragraph it is obvious that the word " understanding " would be immediately taken in its *intellectual* meaning. Suppose now that a personnel or a line management appointment is being discussed and someone asks: " How good is this candidate's understanding of people ? " This question would be immediately interpreted as meaning: " Is he sympathetic, approachable; is he likeable, sociable and popular ? "

It is here that the confusion arises. If we say that John understands people under his command as well as he does the apparatus under his control, there need not be any indication of cosy camaraderie, sentimentality or indulgence. The phrase, which should be taken here in its *intellectual* sense, means that John can fairly accurately predict how his men are likely to behave under any given set of circumstances. Thus, if John understands well one of his subordinates, say George, he will know beforehand George's reaction when he is asked to do a specific job and how he is likely to carry it out; he will also be able to appreciate changes in George's behaviour which are likely to ensue should the conditions of his work be altered.

Furthermore, if John's understanding of George is good and deep enough he may be able to envisage which way George is going to develop in a few years time, whether he is going to become, say, more reliable or whether his negligence is likely to increase. Also John may have a good appreciation of how precisely George's performance is going to change as he becomes older. For example, it is possible that he will become more thoughtful with age; on the other hand he may loose his powers of concentration and, after a lapse of several years, he may become somewhat woolly and vague. Such questions are important if John is to plan what to do with George when the latter becomes nearer to his retirement age. John's understanding of George may be good enough to enable him to predict these changes and to allow for them well ahead.

Moreover, apart from his ability to foresee and to predict, John's own behaviour will influence continuously the present and future course of events. The precise manner in which he supervises George's work will have a powerful effect on George's future development and John may well be able to devise ways and means to bring out George's potentialities to the full, to minimise the detrimental effect on him of daily wear and tear, and perhaps to keep him going strong in spite of increasing age.

All this has nothing to do with sympathy or personal liking. John may treat one of his subordinates sternly, even harshly, although he may like him as a person; with another he may be more lenient and gentle in spite of personal dislike. In both cases—if he is a good manager—because his understanding of them leads him to think that this is the right approach.

This advanced level of the intellectual understanding of human behaviour is reached by thoughtful men and women through examination and reflection on their daily experience. In the absence of an adequate psychological theory to guide a detailed observation and analysis of real life human behaviour, this understanding has to be achieved by private and unaided efforts. As there is no theoretical language, no terminology, a fund of knowledge of human nature acquired in a life-long experience can hardly be conveyed to another person. Everyone has to start from scratch and learn for himself.

A person wishing to increase his knowledge and understanding of any branch of engineering or science will find a profusion of good books and courses on the subject. If his aim is to increase his knowledge and understanding of people the books and courses to assist him in his purpose are few and not very helpful.

The present and the previous series of articles are written in an effort to bridge this gap. Although there is still a long way to go before this purpose is achieved, these articles constitute an attempt to move by stages towards a systematic theory of human relations and of individual behaviour which may eventually be of practical value to managers, and provide a theoretical basis for practical courses in this subject.

APPENDIX

Training in understanding people is actually more complicated than might appear from the present article, as there are certain emotional resistances which militate against it. This matter will be considered on another occasion. From a much more general point of view the question of training in human relations has been discussed elsewhere.[1]

Pioneering work in this field is being done in this country by the Training and Education Division of HM Treasury. A brief account of this is provided by Avice V. Turnbull.[2, 3, 4]

The part of psychology which is most relevant to understanding individual human behaviour, and human relations in small groups is *personality theory*. A recent international symposium[5] being a survey of the current trends and ideas provides evidence of the gulf between the existing psychological theories and the practical needs. More especially the state of affairs in the United Kingdom is clearly exemplified by the articles of the two British contributors, Cyril M. Franks[6] and H. J. Eysenck.[7]

A systematic examination and criticism of the usefulness of some of the contemporary trends in social sciences is provided by Sorokin in his *Fads and Foibles in Modern Sociology and Related Sciences*.[8]

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SURFACE CONDITIONING TO CREATE FORM

Shaping Vanguard Wing Planks

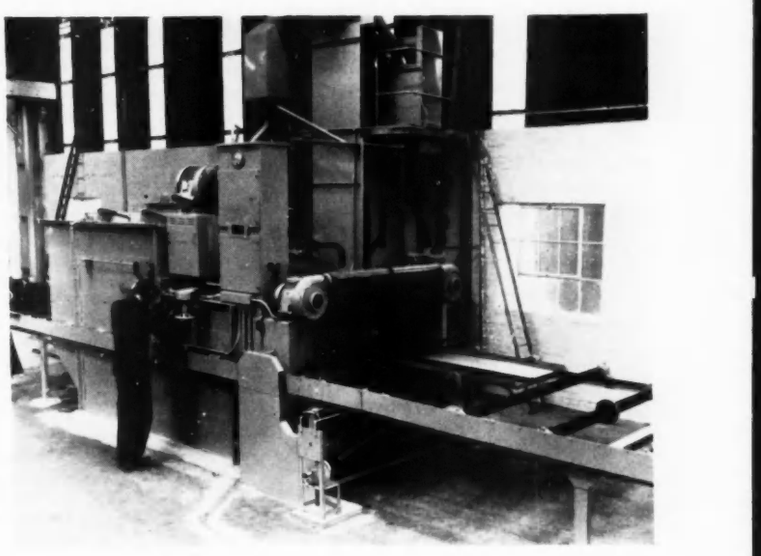
A recent development of shotblasting is the use of controlled mechanical shotblasting to create form. A machine of this type, made by Tilghman's Limited, Altrincham, is in use at the Weybridge works of Vickers-Armstrongs (Aircraft) Limited, forming aircraft wing panels up to 20 ft long by 6 ft wide for the Vanguard airliner. These panels are the integrally-stiffened top and bottom members of the torsion box which forms the main structural member.

As shown in the illustration on the right, the machine consists of a Wheelabrator cabinet with the essential abrasive circulating system; a dust extraction unit is included. It has a 19½ in diameter Wheelabrator unit mounted on an adjustable slide above a roller conveyor which passes through the cabinet. The work is traversed along the conveyor under the wheel, from which a consistent stream of steel pellets is thrown.

The operation of the machine is governed by an electrical control using a cam form to create a combination of the governing factors required to give the desired curvature. Such factors as the rate of conveyor movement, speed of wheel and density of shot are all on a variable control.

The peening action on the surface of the metal relieves inherent surface stresses, while building up compressive stress. Thus, while the release of the inherent stresses creates the uplift of the shot to give form, the surface-peening action strengthens the material in fatigue resistance. In parallel with the action which takes place on the outer surface of the panel, the inner surface is also subject to compressive stress on account of the forming action. This new application of shotblasting opens up a wide field for future developments.

It is interesting to note that this simple and economic operation was introduced at Vickers-Armstrongs on account of the high costs involved in the setting up of cold-forming press equipment. The top and bottom " planks " of the Vanguard wing torsion box are milled from aluminium alloy slab some 2 in thick. About 80 per cent of each slab—initially weighing about 1 ton—is cut away to form the stiffened panel. The slab is checked ultrasonically for cracks on reception, and this examination decides which side of the slab will be milled. After levelling, using a Cramic router, the slab is milled to form the spanwise stiffeners in an Onsrud machine, employing ganged cutters making simultaneous cuts. Edge-profiling and rebate cutting is then carried out on a Cramic router. Now follows the curving process. This is carried out in two stages: the thicker portions of the plank require a preliminary forming operation in a hydraulically operated hot press, followed by the final shot-peen-forming already described.



A Wheelabrator shot blasting machine (right) is used to impart the final curvature to the " planks " (below) forming the top and bottom members of the Vanguard wing torsion box.

KEEPING UP TO DATE

So many things come within the purview of the engineer to-day that keeping abreast of developments is a major problem. No one, perhaps, knows this better than the production engineer, who will at times find himself involved in many branches of his profession, even if only indirectly. One item of topical interest—the Clean Air Act—will serve to illustrate the sort of complication which can arise. Meeting the requirements of the Act may not concern the production engineer directly, but it may well mean that he has to use different production methods. So he will find that the actions of his colleague the plant or works engineer in this connection are of considerable interest, and the two engineers will need to co-operate closely. That is but one example of the changes taking place. How does an engineer keep abreast of them?

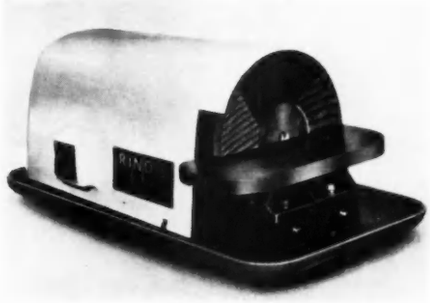
One answer is provided by a course which Nottingham University are running this winter. This course, the fifth of its type, is intended especially for production, works and plant engineers, and comprises 16 evening meetings, to be held from 21 October. The course which has been given the title " Modern Techniques for the Engineer " is organised by a committee which is representative of a very broad cross section of industry as well as the University engineering departments and in accordance with modern ideas, gives ample time for free discussion, half of each two-hour session being reserved for this purpose.

Maintenance, lifting tackle, paints, boilers, radioactive isotopes, automatic control; these are some of the subjects chosen for the 16 meetings. Detailed information can be obtained from the organising Secretary, Engineers' Course 1958, University of Nottingham.

FILING BY POWER

Filing still finds a multitude of uses in various production processes, but it is no longer necessary to do it all by hand; numerous filing machines now exist which will do the job quicker and more easily. Lorant and Company Limited, 98-100 Croydon Road, London, S.E.20, have added a new model to their range of rotary disc filing machines, which, it is claimed, will remove material from four to six times faster than is possible by hand filing.

The machine, which can be bench or column mounted, is known as the " Rindis " 10 in. It is basically simple in design, consisting of a drive motor and gearbox mounted on a substantial tray and concealed under a cover which also acts as a guard to the filing disc. An inclinable work table is mounted at the disc end, and arranged for fixing at alternative heights to suit work of different thicknesses. The teeth on the disc extend to its edge, enabling work to be filed across the complete face or on the corners. Various types of teeth are available, to deal with steel, non-ferrous metals and plastics, and the teeth can be extended on to the disc periphery as well as the face if desired, so that the disc can be used in the same way as a face milling cutter for rapid removal of material in a deep cut. No coolant is needed, and the swarf, being uncontaminated by abrasive or other material, is fully recoverable if required. The file discs operate without heat and do not clog. They have a long working life, and when worn can be re-sharpened cheaply.



Fast removal of metal or plastics is possible with the Rindis 10 *in filing machine.*

Research and Development

THE STORAGE OF ENERGY*

By R. G. Voysey, A.C.G.I., M.I.MECH.E., WH.SCH.†

ENERGY is a recurring theme in British Association papers and the release and conversion of energy by heat engines using coal and oil is probably the most valuable achievement of applied science for most of mankind. This development is a recent and accelerating trend in human history which now receives fresh impetus from nuclear energy.

Just three-quarters of a century ago, Osborne Reynolds surveyed energy storage when he addressed the Society of Arts (Cantor lectures, 1883) on "The Transmission of Energy." He pointed out that there was then at least twenty times as much mechanical energy being developed in the world from animals as from engines. Even in England, where attempts had been made for 25 years to develop steam-drawn ploughs, there were over one million animals involved in husbandry and their aggregate power was more than that of the wind, water and steam engines available for all purposes. To-day the National Grid alone can supply a peak of thirty times this power.

EARLY CONCEPTS

Reynolds saw us at a transition stage in the transfer from solar energy through animal power, to that from fossil fuels. It was then still economic to use steam engines powered with coal, costing less than £1 a ton, to bring maize, costing £6 to £7 a ton, from the plains of America at a transport cost of about £1 per ton rather than apply cheap coal directly. Reynolds attributed this to animal muscles being at least twice as thermodynamically efficient as the steam engines of that day and they are of course more flexible and controllable in small powers.

In his address Reynolds considered all the then available ways in which energy might be packaged and very few can be added to-day. He did not mention flywheel storage, perhaps because he took it for granted, but he did instance storage batteries (particularly the lead accumulator), compressed air and steam accumulators, stressed metals, etc. Reynolds admitted all chemical fuels as "stored energy," but this definition would encompass almost the whole pattern of energy usage to-day, including nuclear energy, and such a wide interpretation is not justified in this paper. There is some justification for classifying as artificial storage that fraction (about one-third) of the country's liquid fuel which is consumed as motor or aviation spirit because, while taken for granted as a common commodity, it was always a selected fuel and is fast becoming an artificial hydrocarbon which is specially contrived for portable power and traction drives.

In this country, and expressed as thermal equivalents, coal now supplies 85 per cent of all our fuel requirements, another 14 per cent is met by liquid fuels and less than 1 per cent is derived, directly as valuable electricity, from hydropower. Industrial power is still based firmly on coal, using about one-fifth of inland coal consumption (say 17 per cent of the country's equivalent fuel usage) to generate electricity at about 28 per cent thermal efficiency. If we compare this with internal combustion engine power generated at about 20 per cent efficiency from particular liquid fuels constituting 5 per cent of the country's fuel usage, it appears that road and air transport use power to an average value of about one-fifth of the industrial electrical power generated from coal. Nevertheless, both figures are prodigious and the development of the liquid-fuelled, internal combustion engine, is a remarkable one which will be mentioned again when the peculiar requirements of traction are discussed in connection with electrochemical cells. Having limited the subject material it is tempting to try to classify it on some simple basis.

CLASSIFICATION

It is difficult to classify energy storage systems very rigidly either by their principles or by their advantages in application. A rough division into chemical, heat, mechanical and electrical storage systems is upset by hybrids like electrochemical cells; a finer division shows a very broad range of physical principles.

Similarly, attempts to arrange storage systems in order by criteria derived from the requirements of application are hampered by the lack of sufficiently general criteria. As in most engineering problems, there may be several possible technical solutions and the most acceptable one will have to satisfy economic conditions which may not be immediately obvious even to those directly concerned with the problem. Such criteria as power to weight ratio and power per unit cost ratio may be helpful, but even the latter may not help in choosing the best economic solution because of special circumstances. Usually such yardsticks are only useful within a narrow field, say electrochemical cells, where other circumstances remain much the same. They are particularly useful for indicating valuable areas of research but most dangerous when used for prophecy.

Reynolds was wise not to prophesy future uses of storage because the pattern of energy usage he described has been changed very much by the development of the three enormous industries of communications, transport and electrical power. In these, several forms of artificial energy storage are used but while important, and sometimes essential, such storage does not generally handle the major part of the power.

STORAGE FORMS

Before speculating on suitable forms of storage for such purposes it is advisable to review storage systems in common use starting with simple thermal and mechanical systems, then moving to electrochemical and mechanical-electrical systems. It has to be emphasised repeatedly that special circumstances are most important in the choice of system. The desired form of energy output is a critical factor.

Where heat energy only is required, its release from the chemical storage of coal or oil is simple and cheap. Hot air, hot water or steam generators are available in a wide range of sizes and their capital cost is usually much less than one-quarter of the fuel they consume in their lifetime, but not so low that one can use their material or fluid content for a large amount of heat storage. Chemical energy is stored much more compactly than heat and in a cheaper casing. Thus one cubic foot of coal will store over 500,000 B.t.u.'s which can later be released at temperatures up to 1,500° C, whereas water will store only 1 per cent of this heat at 100° C and a cubic foot of steam considerably less, even at high pressure.

In special circumstances, for example where a rapidly changing heat load or an extra heat peak load is associated with a relatively inflexible heat generator, hot water storage may be thoroughly economic, as in the Pimlico flat-heating system. When the application justifies such expensive containers, special heat storage media may give benefit. The crystals of some of the soluble salts of the alkali metals have large heats of fusion (around 100 B.t.u. per lb) and, as suggested by Telkes, have been used experimentally for solar heat storage in dwellings.

The cheapest substances are probably sodium sulphate decahydrate $Na_2SO_4\ 10H_2O$ melting at 90° F or disodium phosphate dodecahydrate $Na_2HPO_4\ 12H_2O$ melting around 95° F. Such materials, when taken over the appropriate small temperature range, will store nearly ten times as much heat as the same volume of water taken through the same range. There are a number of more expensive chemicals which might be used, e.g. sodium tetraborate, chromate, molybdate and tungstate. These are valuable in small proportions in the cheaper salts, as nucleating agents to prevent the formation and settling of large crystals which would hinder subsequent re-melting. They also spread the melting range of temperature over a degree or so.

However, usually when storing energy there is more interest in the high-grade forms of mechanical or electrical energy and much more expense or more elaborate engineering is required than for heat energy.

The extreme value of portable high grade energy has forced the development of a number of forms of internal combustion engine in the last half century. Units are available to cover a power range from less than 1 h.p. to over 1,000 h.p. and with weights carying from less than ½ lb per h.p. (aircraft gas turbines) to rather over 10 lb per h.p. for the heaviest diesels. There is no substitute for these heat engines when large amounts of transportable power are required, but their fuel is expensive compared with coal or nuclear heat. The total cost of power as provided by them is then about three times the cost of that derived from the National Grid and they set reliability and maintenance problems. When only small amounts of portable power are required simpler devices may have special advantage.

RESILIENT MATERIALS

Thus the storage of energy by the resilience of metals is bulky and expensive; even if steel is stressed to 40 tons per sq. in, it will store only 1 kWh in 15 tons of steel. Yet there are over ten million storage systems of this type working in Britain. These are our watches, each requiring less than one hundred-millionth of a horse-power for which task a steel spring is consistent, efficient and long-lived. While limited in stress and suffering some defects for engineering applications, rubber and similar plastics will store about ten times as much energy as steel, because of their greater extension under low stresses. Like the steel watch spring they are almost unavoidable in many very small-scale applications but it is difficult to imagine them ever being used deliberately to store even a small fraction of the power used to-day. The combination in such plastic materials of light weight and high energy storage have found special application for resilient mounts, rubber tyres, etc., where they form an indispensable part of the suspension structure of a vehicle. In 1957, 128,000 tons of rubber tyres were manufactured —so such energy storage systems deserve mention although they are hardly within the context of this paper.

A weight falling against gravity is still bulkier than strain-energy storage; a watch spring would have to fall between 10 and 100 ft to develop the energy stored normally in its resilience. Yet an attractive method of storing very large amounts of energy is by pumping water against gravity. This is made possible by cheap hydraulic machinery and the presence at a few sites in Britain of natural features for storing large quantities of water at high level at reasonable cost. Resilience and gravity head are both cases where the energy can remain in storage for an indefinite period without loss. Such relia-

* Paper read before Section G, British Association, in Glasgow on Friday, 29 September, 1958.

† Chief Scientists Division, Ministry of Power.

bility has a high value for emergency and peak generation. This point will be returned to later in the context of peak load electricity supply.

All high grade energy storage systems tend to be expensive in capital cost per kWh stored and therefore more tolerable when there is frequent turn-over of energy in and out of storage. Such a duty is also favourable to storage schemes which suffer a loss of energy with time in storage. An excellent example is a mechanical flywheel which will suffer bearing and windage losses, but stores energy much more compactly than a spring because the energy is stored in kinetic form. There is still a limitation due to centrifugal stress, but with carefully shaped rotors and low-alloy steels it is possible to store up to 5 kWh per ton, i.e., over seventy times as much as by strain alone. All heat engines, particularly the internal combustion engine, depend vitally on flywheels which accept and deliver power up to several hundred times per second and which can, because of their robust mechanical coupling, deliver surges of hundreds of horsepower for short periods. For much longer cycle times the flywheel is not popular, but there are coaches and shunting locomotives in use which employ intermittent electrical power supply for a few minutes at a time to power a flywheel on which the vehicle depends for periods about ten times as long. In a particular instance (the Oerlikon shunting locomotive) two 1½ ton flywheels can store about 12 kWh between full and half speed. The system relies on sub-atmospheric pressure hydrogen around the flywheels to reduce windage and an ingenious electrical system which allows an induction motor to be used alternately as motor and generator over a 2 : 1 range of speed by adjusting values of a condenser across the exciting winding.

A design analysis of flywheels for industrial use shows that it would be difficult to make single units much over 40 tons (about 200 kWh capacity) for high ratios of power to weight, although much larger units could be made with less efficient use of flywheel material. Capital cost would be rather more than £30 per kWh and the overall efficiency of storage would be about 75 per cent at best.

ELECTRICAL FORMS

Just as mechanical energy is more valuable than heat energy, electrical energy is even more valuable because of the ease with which it can be turned into almost all other forms of energy. The storage of electrical energy has attracted research for many decades. There appear no feasible ways of storing electricity more or less directly, i.e., by electromagnetic or electrostatic fields. The highest energy storage achieved with the most compact electrolytic condensers is less than a foot-pound per cu. ft. Electromagnets are more compact but have high resistance losses in storage. Like springs and flywheels these two forms of storage form an essential part of the machines and devices of our everyday life but cannot be considered as compact systems of storage for the large amounts of power required in traction and electrical supplies. To fit the latter cases would require either materials far beyond present possibilities in magnetic permeability or dielectric constant, or field strengths far higher than those which cause breakdown in available insulators (but lower than the fields between protons and electrons in atoms).

In the absence of practical methods for maintaining very strong fields, electrochemical cells have the advantage of direct delivery of electricity with the compact storage of energy by chemical compounds. To Reynolds it seemed impossible to develop large-scale road transport without the electric battery because steam engines could not promise adequate efficiency and the internal combustion engine appeared impractical; the phenomenal development of light, efficient heat engines using special liquid fuel for traction has already been noted. Similarly the electrochemical cell also seemed essential for the practical transmission of electricity, using such cells to balance out discrepancies in supply and demand. The latter problem is now mainly of economic interest because short-term balancing has been achieved by inter-connecting many consumers.

Although the two fields of traction and electric supply have outgrown dependence on the electric cell, the development of the latter is more than a minor triumph.

When Reynolds presented his address the potentialities of common metals for primary batteries had been explored, the lead secondary cell had been improved with Faure's pasted electrodes and the gas-fed fuel cell had been conceived by Grove.

BATTERIES

Improvements since that time have been largely engineering developments concerned with reliability at high ratings and special purpose applications. At the outset, the Faure cell stored about 4 watt-hours per pound weight. Now with much improved reliability, it stores up to 20 watt-hours per lb which is roughly a quarter of the theoretical rating on the pure reactants. Reynolds looked enviously towards the theoretically higher energies of oxidation of iron and zinc. The nickel-iron cell is now the nearest competitor to the lead accumulator for traction and there are special purpose batteries which rely on related metal systems. Electrochemical cells are not produced on a scale comparable with that of rotary generators and, on such a scale, would need large quantities of non-ferrous metals. If for instance the whole British Isles import of lead in 1956 (just over 350,000 tons) was devoted entirely to lead batteries it would provide about 15 million kWh of storage, i.e., less than one hour of peak supply on the Grid.

Aircraft and other lightweight applications have encouraged the application of the silver-zinc cell which is three or four times lighter than the lead cell and conspicuously better than other existing competitors. The zinc cell remains supreme among primary cells, particularly for portable lamps, with a storage of about 30 Wh per lb, but cells based on magnesium have come into commercial use for radio receivers, watches, etc., because of special advantages like long shelf-life or high overload capacity. There are other desirable possibilities, e.g., cells based on aluminium, lithium, boron, beryllium, which metals are becoming commoner if still not cheap. Some of these metals and their organic compounds might also make compact rocket and jet engine fuels (compounds of boron have received publicity recently) but this is a very special use which shows no immediate prospect of large scale application because of expense and the difficulty of fume emission. Such metals are particularly interesting as possible derivatives of cheap nuclear energy supplying an electrochemical industry, and they may offer a partial solution to the problem of traction fuel in a nuclear age.

FUEL CELLS

The energy source for traction several decades hence is an enigma. The transport industry, while vitally dependent on power, requires it only for its service value. In most transport applications, the prime-mover and its fuel constitute less than a third, perhaps less than a tenth, of the whole cost of the service. Consequently, a prime-mover is judged more by the service it gives and there is a great economic urge to develop more suitable prime-movers. This factor, together with the unequalled energy storage of hydrogen-containing fuels, forced the development of the oil industry and of the internal combustion engine. The success of this prime-mover may continue for several decades into a time when extra supplies of hydrocarbon fuels, for one reason or another, have to be elaborately contrived with the aid of nuclear energy. Even now such a system would be cheaper by several times than cells burning electrochemically produced metals whose metallurgical value much exceeds their fuel content value. There is much to be said for electric transmissions in vehicles and small-scale experiments are in hand for the use of hydrocarbon fuels in suitable electric cells.

The most practical fuel cell to date is the Bacon hydrogen-oxygen cell. It has operated at up to 600 A per sq. ft of electrode, i.e., several times the normal rating of a lead cell, but its special fuels (compressed hydrogen and oxygen) are expensive to obtain and store. In the transport application particularly, their bulkiness does much to undo the benefit of the high thermodynamic efficiency of the cell. There are in development other types of fuel cells which are less restricted in type of hydrocarbon fuel but with the offsetting difficulty of securing high ratings with the non-aqueous electrolytes required. Using semi-molten ceramic electrolytes at about 500° C, these cells oxidise fuel gases or the vapours from a number of common liquid fuels, using air as the oxygen source and electric current is generated at somewhat less than 1 volt per cell but with over 40 per cent efficiency. At this early stage they are much heavier than an internal combustion engine of the same power; nonetheless they may have a place in the next decade as an economical storage link between night-surplus nuclear energy and some classes of traction power requirements.

Similarly, they may find some specialised but rewarding place in electrical supply, but the latter can only derive substantial economic benefit from a cheaper method of storing much larger amounts of power in a flexible way.

In its early days the future of electrical supply seemed dependent on providing sufficient storage to reconcile temporary unbalance of supply and demand and the lead-acid accumulator improved operation of individual installations in large houses. It has been mentioned earlier that when consumers are connected into a network there is sufficient diversity of habit to slow down the percentage rate of change of total load to values which can be met by adjusting the supply. Changes of load are temporarily met by a change of speed of all connected plant, evenly spread because of electrical interlock and matched governors. This process takes advantage of the very small amount of flywheel storage in a turbo-alternator rotor, the full speed of which is equivalent to a few seconds delivery of the rated output. Since the supply frequency cannot be allowed to change much, even temporarily, the margin of time while relying on rotor inertia and steam storage in boilers is small and selected plant must be put in or out of service quickly.

MEETING PEAK LOADS

When full advantage has been taken of consumer diversity within a region there is still some gain in transferring a few per cent of power between regions. But long-distance transmission, although essential to minimise the plant and to safeguard breakdown, is quite expensive, particularly in capital, and the process is on diminishing returns. Ultimately there emerges the stark hour-to-hour pattern of average consumer habits with superimposed weather and seasonal variations. Provided there is sufficient reserve of plant, these variations are an economic problem now met in this country entirely by bringing in older, less economic plant for consumption peaks. While this method of meeting peaks is simple and obvious technically, the total costs involved are so large that small percentage savings offer large absolute economies and optimum programming arrangements must be very carefully chosen. There are a large number of factors involved in the present peak problem besides the obvious ones of the inefficiency of old plant balanced against its low capital charges. Some of the factors are hard to assess, e.g., the insecurity involved in using older plant. Other factors have an arbitrary flavour in that they can only be guessed at by extrapolating existing trends, e.g., the rate of growth of load in the future and the rate of growth of efficiency of new plant in the future. An under-estimate of the former, for instance, will result in enforced use of more of the obsolete and inefficient plant with correspondingly higher generation cost.

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Quite apart from the complexity of the decision involved every year in planning future extension of generation, the daily programme of putting plant into action is complicated by factors of inter-regional exchange, weather variations, etc. Where factors are assessable, such a complex situation can be improved by the use of computers and other system aids but there may be insufficiently precise information to decide the wisdom or otherwise of installing plant specially designed to meet peak loads. However, such complicated and important economic problems are not uncommon and, given a good prima facie case this one should be soluble by judicious experiment on a scale sufficiently large to give the missing information, but not so large as to be wasteful of resources if the experiment proved unrewarding. For various reasons special peak-load supply plants have never been considered economic in this country, but the situation is changing slowly and may be modified by the growth of nuclear energy. It is against this difficult and controversial economic background that pumped water and compressed air storage have to be considered.

Apart from reliability, and low maintenance cost, such systems of energy storage must offer reasonably low capital costs and an adequate regeneration efficiency of the stored energy. Both these requirements are stringent to-day because in coal-fired plant the capital cost of generating plant per kWh sent out is rather less than half the fuel cost. In nuclear plants of foreseeable design this relationship may be reversed and 24-hour operation is most desirable. This may make energy storage systems more valuable in comparison with older generating plant for peak or even for supplementing day-plateau supply.

PUMPED STORAGE

Before describing these storage processes it should be pointed out that possible alternative uses for night-surplus nuclear electricity are massive new electrochemical or metallurgical industries, but the latter are likely to have even higher capital costs per kW than generating equipment and may therefore be unsuitable for such loads.

Water is cheap and where there are natural geological features which can be cheaply adapted to store water at hundreds of feet above a low-level reservoir, pumped water storage can be cheap enough to help the economics of supply. At 1,000 ft head, about 50 cu. ft of water must be stored to provide a kWh of power. Catchments for normal hydroelectric supply have to hold almost a season's reserve of water but a pumped storage scheme need store little more than one day's peak supply.

The machinery problem is comparatively simple as hydraulic pumps and motors are inexpensive and efficient enough with cheap dual-duty motor-alternators to give an overall efficiency of 75 per cent to the system. Pumped water storage installations have been used on the Continent over the last 70 years and a 300 MW installation at Blaenau Festiniog, North Wales, should come into operation in 1960. This plant will give very valuable information in British conditions. There are only a few feasible sites in Britain for such plants and their installation may be thought to threaten amenities.

In 1906 in Paris there was a power network operating on compressed air. Little information is available but it is believed that up to 25,000 h.p. could be delivered. Compressed air lacks the extreme versatility of electricity but stores energy compactly. At 20 atmospheres pressure, each 10 cu. ft of storage volume will contain about 1½ lb of air which can be displaced and expanded in cheap turbines to provide up to 1 kWh of energy (depending on the temperature to which the air is raised before it is expanded through the turbines).

If this air were contained in welded steel tubing of several feet diameter, stressed to 5 tons per sq. in, about $\frac{1}{20}$ cu. ft of steel weighing 25 lb would be required for each 10 cu. ft of storage and the capital cost would exceed £1 per kWh stored. If this storage were not to add more than 0·1*d* to the cost of every kWh delivered it would need to be used for at least 3,000 times, that is something like ten years to replace cost and interest. A larger spherical container would use less steel but would cost more to fabricate and be a greater hazard.

UNDERGROUND AIR STORAGE

However, it is possible to store air underground, safely and economically. Such storage can be, variously, in rock caverns, washed out cavities in salt stratum, pillared caves in gypsum mines, sealed-off mineral workings of suitable type or in the interstices of sand and gravel beds where these are in the form of lenses or domes sealed with impervious strata. The order above is roughly that of best application to storage and, more approximately, the order of descending cost per cubic foot of storage. Even specially prepared cavities in rock promise much cheaper storage than steel tubing and may provide economic air storage.

The requirements of such a system are:

(1) The underground storage reservoir with ducts for supply and return of air and water.

(2) Air compressors and expansion turbines electrically coupled to the Grid as necessary or arranged to rotate in vacuum when not required.

(3) A surface reservoir of water to displace, by natural head, the whole of the air from storage. This is desirable to give constant head on the air machines and full utilisation of storage space.

(4) If power is to be delivered for more than a very few hours peak per day, air reheating arrangements are economically justified even if they have to use oil fuel. At most, the latter would be 3 per cent of the whole fuel requirement for the energy produced.

Some technical examination has been made in this country and abroad of the possibilities, problems and costs of such an installation and studies are still in progress. Most of the above-mentioned kinds of underground cavity have been used overseas to store compressed air or gas, but the high rates of air flow to and from storage and the warmth of the incoming air are novel and may set new problems. Those which can be imagined do not seem to be very serious. Since the air is to be at a steady pressure of less than half the stratum pressure, there should be little fatigue or sealing failure of prepared cavities. Even if warm air is sent down, the heat loss from the cavity has been calculated not to be large after the first few hours of operation, provided the heat in the displaced water is conserved. In the particular case of the cavity in salt, the differential solubility of salt with small temperature changes might be troublesome. Also the storage of air in gravel beds is difficult technically because an elaborate arrangement of "capillary" air shafts is required to increase the permeability for rapid air and water movement.

For operation at 20 atmospheres, cavities at 700 ft depth would be required, and the energy output per cubic foot of displacing water is over eight times that from pumped water storage at 700 ft head. Greater depths would make more economical use of the cavity and displacement water because a greater weight of air can be stored in a cubic foot and also because the energy stored per lb increases with the logarithm of the storage pressure. Sufficiently cheap cavities at great depth might allow closed-cycle operation on the air with a high pressure of operation but a small pressure ratio corresponding to two cavities each at different depths. The same charge of air would then be recycled for every day of operation. The air would be expanded from say 60 atmospheres pressure in the smaller cavity down to 20 atmospheres pressure in the larger cavity when power was required and compressed back again during the subsequent night hours. This would improve the design and reduce the size and cost of the machinery, heat exchangers and ducting.

There are many other variants on such storage schemes. Thus it may be quite possible to make economic schemes which do not use constant pressure operation and water displacement, but the scheme outlined is probably the safest for initial consideration.

CONCLUSION

Looking back over all the ways of storing energy it is seen that for compactness at reasonable cost there is nothing to surpass internal combustion engine fuels and that the several forms of energy storage vary tremendously in their capabilities in a given situation. Although the very substantial application of storage is limited by cost in competition with the direct generation of mechanical or electrical energy, it is also seen that there is an indispensable amount of energy storage in almost every engineering device. Moreover, the inevitable concentration of nuclear generation in large central stations may involve a greater dependence on large-scale storage of energy for economic reasons in the case of electrical supply or for operating convenience in the case of traction.

SILICON DIODE FOR COMPUTERS

Diffusion Technique Gives Short Switching Time

A silicon switching diode suitable for high speed computers was described at the recent Western Electronic Show and Convention in a paper prepared by J. H. Forster and P. Zuk of Bell Telephone Laboratories, 463 West Street, New York 14. The diode, known as the 1N696, has a switching time of about one millimicrosecond. Other characteristics claimed include low capacitance, low forward dynamic resistance, low direct current in the reverse direction, and good reliability. Diffusion techniques were said to play a large part in achieving such characteristics.

The p-n junction in the 1N696 is formed by diffusing boron into n-type silicon. Capacity is kept small by limiting the junction to a diameter of about 0·005 in. This is accomplished by ultrasonically cutting circular mesas on a diffused and plated slice. Actual zero-bias capacity, including the enclosure, averages about 2·5 picofarads. Low forward dynamic resistance is achieved by starting with silicon having a resistivity as low as possible, consistent with other limitations.

The direct current in the reverse direction is less than 0·015 μA at 20V. Breakdown is in excess of 40V, which is more than adequate for the low voltage levels used in high speed computing.

Recovery time in a junction diode depends primarily on the time required for the minority carriers in the body of the diode to recombine. This time can be shortened by the addition of suitable recombination centres. In silicon, gold acts as an effective centre, and in the 1N696, gold atoms are introduced by solid state diffusion to decrease the recovery time. By varying the concentration of the gold atoms in the silicon, recovery times of 0·5 to 20 millimicroseconds can be achieved. Sufficient gold is diffused into the 1N696 to ensure an average recovery time of about 1 millimicrosecond.

To provide long life, vacuum baking is carried out at a temperature in excess of 300° C and the enclosure hermetically sealed. Life tests indicate that the completed diodes have a life expectancy in excess of 100,000 hours, based on the assumption of an exponential failure rate. As more data are accumulated, this figure is expected to increase substantially.

HEAT AND THE ENGINEER

By Professor O. A. Saunders, F.R.S.

*Presidential Address to Section G of the British Association**

DECIDING on the subject of this Presidential Address gave me some difficulty, since for one who has spent most of his life in education there was a strong temptation to speak on the many problems which confront us in teaching engineering to-day, about which most of us have ideas and are only too willing to express them. But I should not care to risk comparison with the inspiring address by last year's President, Sir David Anderson, on this subject. There was also some attraction towards such topics as gas turbines and nuclear power plant with which I have been connected from time to time, and which perhaps have a more popular appeal than the topic I have chosen, but in the end it seemed that the subject of heat, and particularly heat transfer, is of such wide importance in engineering today that it offered the best scope, especially since it is the subject on which most of my own scientific work has been centred.

HEAT AND HEAT TRANSFER

I like Thomas Tredgold's definition of engineering as the " art of directing the resources of nature to the use and convenience of man." Pursuing this art the engineer, whatever his speciality, will always encounter problems of heat and heat transfer which extend from one end of the field to the other. Apart from the fact that we still know of no practicable way of obtaining power from fuels without first passing through the form of heat, the vast majority of physical and chemical processes used in industry are heat-controlled or heat influenced, as indeed are many natural phenomena including life itself. The engineer meets heat problems in both large industrial plant and small domestic appliances. They occur for example in the steam power plant and the steam laundry, the industrial furnace and the domestic cooker, the cooling of the missile or satellite and the business of keeping himself cool or warm in his home, the commercial evaporator or distiller and the ladies' hair-dryer. Only too frequently heat is in the wrong place and arrangements have to be made to transfer it to somewhere else often at great effort and expense.

The energy stored in the earth is found as chemical energy of fuels, or nuclear energy, and while it is not very difficult to convert it into heat. it is rarely then where we want it. with the notable exception of the internal combustion engine. Some of the most costly parts of Calder Hall are the enormous heat exchangers needed to transfer the heat from the carbon dioxide to the steam, and indeed the reactor itself is largely a heat exchanger and many of the most difficult problems of reactor design arise from this fact. And in all appliances in which temperature has to be regulated by the inflow or outflow of heat, complicated heat transfer problems arise, the successful solution of which is often vital to the performance of the plant.

It is perhaps surprising that such a familiar concept as heat should still offer any difficulty of definition to the engineer. The history of thermodynamics and the controversies of the last century no longer greatly excite the engineer, but the importance of absolutely clear understanding of terms used cannot be over-emphasised, especially with so many new developments coming along, and I was surprised to find when sitting recently on a board of advisers for the appointment of a university reader in applied thermodynamics, that apparently very suitable candidates could not answer satisfactorily the simple question " What is Heat? "

The best textbooks and especially the great writers on thermodynamics, such as Gibbs and Planck, are of course crystal clear on the subject, but the engineering student of today is often loosely taught to regard heat as a property of a system, thereby confusing it with temperature and internal energy. The difficulty disappears immediately if we consider heat as a transient process of flow between systems of different temperature. It is also rather dangerous to teach the subject in terms of molecular energies and velocities unless the kinetic theory of gases is properly developed, including its statistical nature. There is however no real difficulty in presenting formal thermodynamics to engineering students, any more than in presenting mechanics. These matters are not merely of academic interest when we have such new developments as electronic heat engines, molecular flow of rarefied gases, and so forth. Inventors, and even reputable scientists, still appear in my department at the frequency of one or two per year, claiming to have circumvented the second law of thermodynamics, but the inevitable conclusion is that the inventors themselves do not understand the law.

The struggle to increase the efficiency of conversion of heat into power by conventional methods seems to have reached the stage when further progress is difficult and costly. To discuss the prospects of steam and gas-turbines and other kinds of power plant would be a subject in itself, but it is interesting to observe how often progress depends in the end upon the solution of problems of heat transfer. For example, in steam power plant one of the crucial problems is the design of the superheater to give satisfactory heat transfer without burning out the tubes. In the gas-turbine, leaving out aircraft applications, the fuel consumption could easily be reduced from its relatively extravagant figure in the simple gas-turbine to a value not far off that of the diesel engine if a really satisfactory heat exchanger could be developed. And in the nuclear reactor, as already mentioned, one of the main engineering problems is to achieve a sufficiently high coolant leaving temperature for a good thermodynamic efficiency without excessive heating of the fissionable material.

Before leaving this subject it is perhaps worth referring to the possibility of some form of direct conversion of chemical or nuclear energy into power. The fuel cell, which does this for chemical energy, has been known for many years, but the main difficulty is the very low output from a given size of apparatus, which renders it impracticable for all but a few special applications. This appears to be fundamentally linked with the small temperature changes involved. Another recent development which has attracted interest is the possibility of converting heat into electricity by some form of electrical apparatus in which a flow of electrons can be intensified by the application of heat. The American General Electric Company have experimented with a thermionic converter in which an electric flow between a hot plate and cooler one abstracts heat from the hot plate. This would eliminate the necessity of the elaborate turbo-generators and heat exchangers needed in a conventional plant, but so far the device appears to be possible only on a very small scale, suited, for example, for providing current for radar sets in remote districts. At MIT they have recently reported success with a device of this kind with an efficiency of 13 per cent.

Both of these are heat engines in which the working medium is an electron gas and the work is abstracted as electrical energy when the electrons move in an adverse electrostatic field. Even if the efficiency of such apparatus were not more than 20 per cent they would still have applications because of the elimination of costly turbines and generators; it is, however, to be remembered that on a larger scale the getting rid of the remaining 70 to 80 per cent as waste heat may be a formidable problem.

Still more interesting is the conversion of energy from nuclear sources directly into electricity, on which very little is yet known. For nuclear energy produced by fission as in existing nuclear power plant, the problem looks insoluble because the bulk of the energy is produced as kinetic energy of uncharged neutrons which appear as heat when the particles are reduced to rest in the surrounding material. On the other hand if a fusion type of process can be developed by some form of electrical discharge, energy may be produced in the form of directional motion of charged particles and it might be possible to extract some of this in a magnetic field as electrical power. Indeed this may be the only way in which such energy could be abstracted, since the problem of transferring heat at a temperature of hundreds of thousands of degrees to a solid surface without vaporising it may be extremely formidable.

The science of heat transfer remains based on the three elementary processes of radiation, conduction and convection, but to these have been added heat transfer with change of phase, as in evaporation and condensation, and with chemical reaction. The greatest difficulties of the subject arise from the complicated conditions in which these processes operate in practice. The basic differential equations of conduction and convection have been known for over a hundred years, but the boundary conditions for which solutions existed were for a long time so restrictive as to be of very limited use to the engineer. During the last quarter of a century the situation has changed greatly with the advent of numerical methods, including relaxation techniques and of digital and analogue computers. In the field of conduction today, for example, even for unsteady state problems, there is no reason why any problem, however complicated the boundary conditions, cannot be solved, given the necessary time and equipment. As an example, the temperature distribution in an axisymmetrical steam turbine rotor during the initial starting up period has recently been found in my department by using an electrical resistance analogue computer, this investigation being a necessary prelude to studying the thermal stresses involved, which are crucial matters to the designer. The shape of the rotor is very complicated and indeed it is from the shape that the problem of stress concentration arises.

In convection, which is perhaps the most difficult branch of heat transfer, great progress has been made in solving the boundary layer equations for laminar flow for both free and forced convection and, as in the case of conduction, we are now in the position that with the aid of computers we can solve almost any problem. For example, solutions have been given for forced convection laminar boundary layer flow with temperature-varying physical properties, with and without fluid injection or removal at the surface. Recently cases of non-uniform surface temperature have been treated, starting by the stepped temperature distribution, which leads to the case of any arbitrary temperature distribution at the boundary. In free convection

* Address delivered at Glasgow on the 29 August 1958.

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also, many new cases such as uniform heat input to a vertical plate have recently been solved. In fact, to sum up, there is not much research interest left in solving laminar flow convection problems since it is now largely a question of feeding the particular conditions into a computer.

We are left, however, with turbulence, and here the position is quite different, as indeed is the case in any branch of fluid mechanics. Unfortunately the pace of modern industry is such that the flow is turbulent in the majority of applications. We still have to rely on experiment for finding turbulent heat transfer, even though considerable progress has been made towards understanding the temperature distributions in fluids in turbulent motion. The fundamentals of the relation between heat transfer and friction for turbulent flow were given in the middle of the last century by Osborne Reynolds, and we still use developments of his method today. An example of this is the gas-cooled nuclear reactor in which the need for minimum pressure loss in the carbon dioxide flow is very important since some 4 per cent of the final power output has to be fed back to drive the circulating fans, reducing the overall efficiency from 25 per cent to 21 per cent. The particular geometrical conditions of this application are a little unusual in that the gas flows through a long annular passage with heat flowing into it from a finned surface on the inner side, the heat flow being distributed in a non-uniform manner controlled by the neutron-flux distribution, a set of conditions obviously not to be found in the text-books. The flow is turbulent and the problem is to design the fins on the inner core so as to give satisfactory heat-transfer coefficients everywhere with a minimum of pressure loss. This problem is actually a new and complicated variation of a very old engineering heat-transfer problem, namely to get heat transfer without excessive pressure loss by varying the geometry of the boundary such as by roughening, grooving or other devices, a topic on which large numbers of patents have been taken out for boilers and heat exchangers.

It has always seemed to me that, in very oversimplified terms, success depends on creating turbulent eddies in the places where the temperature gradients are a maximum and so far as possible to produce larger and slower-moving eddies rather than smaller faster ones, although, of course, there are limits to the extent to which this can be done. The developments in design of fins for the uranium cans in the new power stations will be followed with much interest.

DIMENSIONAL ANALYSIS

Some 30 years ago the engineer received much help in correlating experimental heat transfer data, particularly for turbulent convection, by the use of dimensionless groups of variables, and the use of Reynolds, Prandtl, Grashof, Nusselt and Mach numbers is now universal, with more recent additions such as the Schmidt number for evaporation, Knudsen number for rarefield gases, and so on. It is rather remarkable that only during the last few months a new extension of dimensional analysis has come to light, namely vectorial dimensional analysis which is based on the consideration of vectorial lengths in, say, the three directions of Cartesian co-ordinates, as independent fundamental units, instead of using only one unit of length as in ordinary dimensional analysis. This immediately leads, for laminar flow, to the relation $Nu/\sqrt{(Re)} = f(Pr)$ for forced convection and to $Nu/\sqrt[4]{(Gr)} = F(Pr)$ for free convection, with an interesting extension to cases of. combined forced and free convection by including an additional independent variable group Re^2/Gr on the right-hand side.

It may be objected by the mathematically minded that these results follow immediately if we write the basic boundary-layer differential equations in non-dimensional form, which is indeed true, but the approach through dimensional analysis is of fundamental and educational interest, and may be of value in studying new problems. It is also of interest that vectorial dimensional analysis applies only to laminar flow, and not to turbulent flow; in fact, it distinguishes the two on purely dimensional arguments. The reason, of course, is that in turbulent flow the directions of local viscous shearing and local conduction are not exclusively parallel to the surface, as they are for laminar boundary layer flow, with the result that prescribed vector dimensions cannot then be attached to the viscosity and thermal conductivity.

Turning to radiation, apart from determination of surface emissivities for different wavelengths, the main unknown fields are semi-transparent media, and radiation from clouds of particles in the important practical case of the luminous flame. The real difficulty in all these problems lies in determining the local radiation and absorbing the properties, which in the case of flames are linked with the rate carbon formation in the combustion process. These and other fundamental problems will be referred to again later with reference to some practical applications.

In the general field of heat transfer with change of phase, progress has been made recently with the solution of boundary-layer problems with simultaneous heat and mass transfer and we are now able to treat theoretically such matters as combined evaporation and heat transfer from wet or subliming surfaces.

The remainder of Professor Saunders' address was devoted to some practical applications involving heat-flow, and will be published next week.

Design

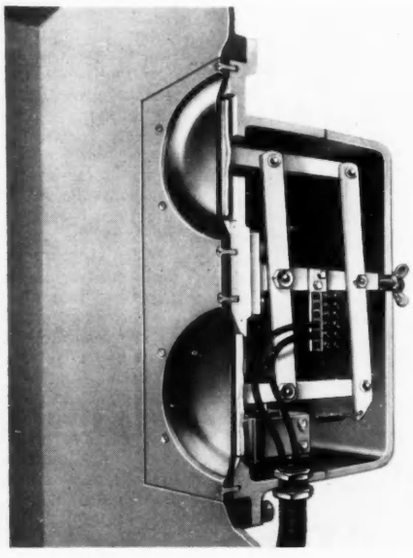
LEVEL INDICATOR FOR SILOS

For controlling the level in silos of liquids, powders, granular and flaked materials, a double-diaphragm level indicator has been developed by Blaw Knox Limited, 94 Brompton Road, London, S.W.3. Designed particularly for installations where pneumatic conveying is employed, it is unaffected by build-up of air pressure or dense dust within the silo.

The unit comprises two diaphragms arranged vertically, one above the other, and coupled by a spring-loaded "even" beam which is connected to micro-switches. Two micro-switches are supplied as standard and they can be arranged for the automatic control of material flow into the silo or, alternatively, to actuate warning systems.

As material within the silo rises and covers the lower diaphragm, its weight deflects the diaphragm, which rocks the beam and trips one or more micro-switches to stop the material flow or actuate warning devices. Conversely, as material level falls and weight is removed from the lower diaphragm, the spring-loaded beam resumes its original position and operates the switch to re-start material feed to silo or actuate warning devices. For extreme conditions, such as in high temperatures or when handling unusual materials, special diaphragms can be supplied.

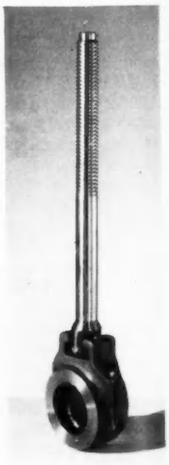
ALLOY GATE VALVES FOR HIGH TEMPERATURE USE



An improved range of alloy gate valves, with better shut-off power and with much longer periods between maintenance, has been introduced by Langley Alloys Limited, Station Road, Langley, Bucks. These valves use no plastics or rubber seatings, and accordingly are not subject to the temperature limitations that apply to most non-metallic seatings.

The essential improvement in the new type of valve lies in the use of specially-machined faces on the wedge, or gate, of the valve, consisting of a series of concentric annular lands with grooves between, as shown in the illustration on the right. This "Multi-seal" feature, as it is known, is now available on all Langley alloy gate valves of 1½ in bore and larger, in the 150, 300 and 600 classes. The materials available include Langalloy 18/8 stainless steels, Langalloy 20V special stainless alloy, Hydurax 1 aluminium bronze, and special nickel alloys produced to order.

Many advantages are claimed for the Multi-seal design. First, it has been proved by many extended tests that the life of the seating faces is more than doubled before re-seating is necessary, and this long life applies in instances such as where the valve is made in austenitic stainless steels, and the wedge and body seat facings are of the same alloy quality. Secondly, the complete and positive shut-off which is achieved, even when body movement takes place as a result of temperature variations or line stresses, and even when slurries are handled or foreign matter is present in the fluid, is, in many applications, of very great importance in ensuring optimum plant operation.



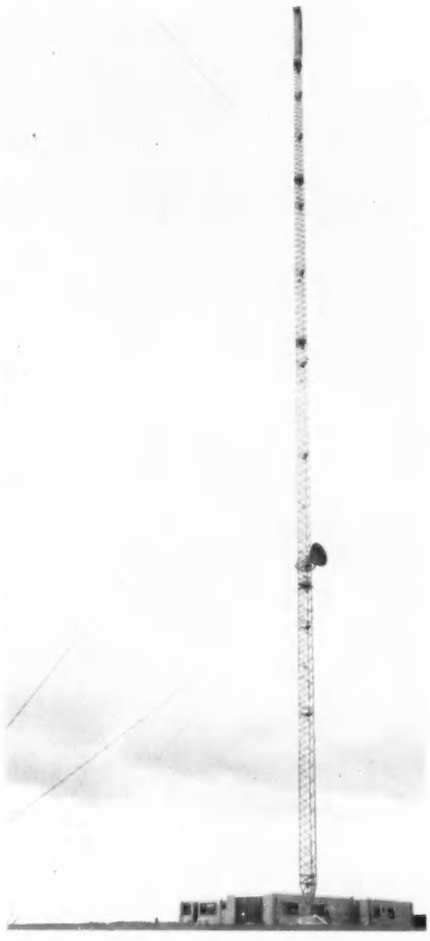
In the Multi-seal range of alloy gate valves, the wedge, or gate, has machined on it a series of concentric annular lands with grooves between.

Continuing **Design**

TELEVISION FROM THE ISLE OF WIGHT

ITA Transmitter Linked to Southampton Studio

The Independent Television Authority's transmitting station at Chillerton Down, Isle of Wight, recently came into official programme service. It is designed to serve some 2¾ million people living within the area bounded by Weymouth in the west, Newbury in the north, and Brighton in the east. Explaining the significance of the new station, the Authority's chief engineer, Mr. P. A. T. Bevan, said "The opening of the Chillerton Down Station, to serve Southern England, marks the first step in the second big stage of independent television's task of providing an alternative programme on a full national basis. The first stage was completed when the St. Hilary Station went into service at the beginning of this year, for this marked the provision of the alternative programme to the densely-populated regional areas of London and Home Counties, the Midlands, the two halves of the great Northern area, Central Scotland, and South Wales and the West Country. Chillerton Down is the first of the next group of stations, all of relatively high power, which will fill in the important areas as yet unserved by the first six transmitters."



The 750 ft mast carries a 16-stack array at its top. The paraboloidal dish attached to the lower part of the mast links the transmitting station to the Southampton studio.

Mr. Bevan pointed out that it is the Authority's view that the Government's declared policy for the utilisation of Band III (170 to 224 Mc/s) had been justified by the practical experience gained with existing stations in this band. The reliability of the service had reached all expectations, and the carrying power of the signal had exceeded them. He also said that had the Authority been given the whole of Band III, as they had wished in the first place, it would now be technically possible for them to provide a second independent service in any area where such provision was considered desirable.

Marconi's Wireless Telegraph Company Limited, Chelmsford, Essex, have supplied and installed the complete transmitting equipment at Chillerton Down, including the aerial systems. Two 4 kW vision transmitters (type BD366) and two 1 kW sound transmitters (type BD270A) form the main equipment at the station. The vision transmitters are the first of a new type, in which a considerable reduction has been made in the number of valves used—this has permitted a straightforward layout and simple cooling. In fact, the need for underfloor ducting to carry the cooling air stream for the equipment has been dispensed with, the cooling arrangements being such that the transmitter can be installed on any flat floor surface. The heated air from around the valves is extracted and discharged to augment the room heating, where necessary.

The aerial is a twin-eight stack array—used at present as a 16-stack array—mounted on a 750 ft mast of triangular cross section, a general view of which is shown in the illustration opposite. The mean aerial height is 1,250 ft above sea level. A minimum of back radiation across the English Channel is obtained by means of the directional radiation pattern devised. Maximum radiation extends in an arc across the South Coast of England. In the forward direction, the aerial gain is of the order of 16 dB over an arc of 180°. It is the intention of the ITA to use only one pair of vision and sound transmitters at any given time, and to use the other pair as a standby set. As a result of this arrangement, the aerial fed by a vision output of 4 kW provides an effective radiated power of about 100 kW over the main arc. Channel 11 has been allocated to the station (vision 204·75 Mc/s, sound 201·25 Mc/s).

At Chillerton Down, the usual expansion joints in the long run of feeder line, connecting the transmitter to the aerial, have been dispensed with. Instead, the cable is supported flexibly by means of runners and springs so that expansion can take place without any significant stress along the length of the run.

The transmitter is housed in three standard cabinets that stand side by side to form a continuous front, 7 ft 6 in high and 3 ft 9 in deep. Viewed from the front, the right hand cabinet contains the radio frequency stages and the final stages of the modulator, with the cooling fan in the lower compartment. The central cabinet houses the low power units, and the left hand cabinet houses the main and auxiliary high tension rectifiers and miniature circuit breakers.

Switching on is governed entirely by the circuit breakers and by two contactors. These provide the necessary interlocks to ensure the correct sequence of operation, and also include overload circuits to protect the transmitter in the event of a circuit fault. † In an unattended version, also produced by the company, two additional contactors provide the facility for switching on the transmitter from a remote point.

The type of crystal drive used is dependent on the client's requirements, in as much as it can be mounted in a centre cabinet or externally. A single tetrode stage operating as a tripler accepts the drive output and feeds a tetrode radio frequency stage. The output from this unit drives the penultimate stage, which consists of four tetrode valves in parallel push-pull. The final radio-frequency amplifier employs two tetrodes in push-pull. In this stage, the tank circuit has been combined with a vestigial sideband filter which shapes the response to give appreciable cut-off for the vestigial side-band, thus avoiding the use of an external filter—except in cases where CCIR (Comité Consultatif International Téléphonique) standards are involved. The tuned circuits are of open line construction. It is possible to use the transmitter for colour transmission to NTSC (National Television System Committee) colour standards, with 405, 525, or 625 lines. For higher outputs, an 18 kW amplifier is available.

The programmes broadcast from Chillerton Down are carried there over a link provided and operated by the Post Office. The link has two parts. One carries the ITA national network programme from London to the Southern Television Studio at Southampton. The other carries the national programme, local programmes, and advertising material inserted at Southampton to Chillerton Down. Microwave relays make up the larger part of the 125 mile link.

The first part of the link comprises a two-hop microwave path, 83 miles long, from Museum Telephone Exchange, London, to a receiving terminal situated in the BBC television station at Rowridge, Isle of Wight. Common aerials and feeders carry ITA and BBC signals, waveguide branching filters being used to separate the signals. An intermediate repeater station is situated 43 miles from London, at Golden Pot, near Alton, Hampshire. The London-Isle of Wight link operates in the 4,000 Mc/s band and was manufactured and installed by the radio experimental branch of the Post Office Engineering Department. Travelling wave tubes are employed and transmitter powers of about 1 watt are used. The aerials are paraboloidal dishes of 10 foot diameter.

Three and a half miles of co-axial cable links Rowridge to Chillerton Down. Between this station and Southampton, radio equipment in the 2,000 Mc/s band operates, the equipment being provided and installed by the General Electric Company Limited, Coventry, under Post Office contract. Triode valves are used as mixers and amplifiers, the transmitter output being about 2 watts. The 12 ft paraboloidal dish that serves for both transmission and reception can be seen in the illustration. Interference between transmitters and receivers is avoided by arranging the feeders to enter launching units which illuminate the paraboloid in a way that separates the sent and received signals by orthogonal polarisation.

The signals from Chillerton Down travel 18 miles to the Southampton exchange, where they are transferred to a co-axial cable for the 1·5 mile path to the Southern Television Studio. Throughout the whole link, the equipment is duplicated—except for the aerials—to avoid interruption of service by equipment failure.

An outside broadcast unit has been supplied by EMI Electronics Limited, Hayes, Middlesex, to Southern Television Limited. The vehicle is equipped with three camera channels and a standby, vision and sound mixing facilities, and monitors and ancillary equipment. Type ML 4A microwave links have been used to relay the broadcast from the vehicle to the main Southampton studio. Transmissions have been made successfully from an ice rink, a cricket ground, and the Hamble River Yachting Centre.

Continuing **Design**

PROGRESS IN NAVAL ARCHITECTURE

A Review of the Principles of Ship Resistance, Strength, Performance and Vibration

By J. F. C. Conn, D.SC., M.I.N.A.

Professor of Naval Architecture
University of Glasgow

Concluded from page 353, *September* 12

The concluding part of Professor Conn's paper to Section G of the British Association is concerned with the strength and vibration in ships. The first part published last week dwelt on hull resistance and the prediction of of power requirements.

STRUCTURAL STRENGTH

The builder of merchant ships has little interest in the academic aspects of structural theory. His primary objectives are:

(i) adequate structural strength; and

(ii) arrangement of structural material to permit of easy erection and efficient connection, i.e., economical fabrication.

Any proposed redisposition of hull material must therefore tend towards a hull which is either lighter or cheaper to construct, or preferably both.

The strength of merchant ships has been left almost entirely to the Classification Societies and this has been justified by experience over many years. It also has the merit of relieving the builder of much laborious calculation. In compiling their rules, the societies must postulate certain average conditions of loading, etc., and such few failures as do occur are normally confined to cases where circumstances have been exceptional so that the assumed average conditions have not been realised in practice.

It has been claimed that the structural design of ships of most classes has now reached a stage of effectiveness where the stress induced in the main structure, when among waves of the lengths and heights usually encountered in service, is seldom responsible for damage to the hull structures. But this does not imply that further progress is impossible or that our knowledge of the behaviour of ship structures under load is adequate. The use of electric welding and the introduction of new materials may conceivably lead to changes, not only in the nature and distribution of structural material, but in the erection of the hull on the building berth.

LOADING AND STRESS CALCULATION

The design of all structures is based on experience, and the importance of this statement is not diminished by the fact that it needs very judicious interpretation. The object of analysis (experimental or mathematical) is to extend the range of experience to give a correct basis for comparison between structures already built and those projected, and to investigate the possibilities of novel designs.

The calculation of the stresses in a ship's structure under various assumed conditions of loading and support is essentially an empirical process. The stress values so obtained may be purely nominal, although they are often quoted and considered as actual.

The conventional assumptions in longitudinal strength calculations may be stated as follows.

(i) The vessel is assumed to float in waves of length equal to the vessel's length between perpendiculars, the height of the wave being one-twentieth of the length.

(ii) Bending moments are calculated for the two cases when the centre of the ship length is

(*a*) at the crest of the wave, and

(*b*) at the trough of the wave;

these are considered to be the maximum bending moments.

(iii) The form of the wave is trochoidal.

(iv) The ship is in the upright condition and is poised on the wave at right-angles to the line of the wave crests.

(v) The pressure at any point in the wave is proportional to its depth below the trochoidal wave surface.

(vi) The volume of water displaced in the wave equals the displacement of the vessel.

(vii) The centre of gravity of the loaded vessel is located in the same vertical plane as the centre of buoyancy.

Within the writer's knowledge, assumption (ii) is universally accepted. It is, however, a requirement which cannot always be satisfied. With present-day freeboards it is impossible to balance a loaded oil-tanker on the standard wave in the hogging condition. Assumption (ii) is unsound, as will be shown later, and assumptions (iv) and (v) imply the neglect of dynamic effects.

RATIONAL LOADING ANALYSIS

If the total vertical longitudinal bending moment sustained by a ship in a seaway is considered as the sum of two components:

(*a*) the still-water bending moment due to the unequal distribution of weight and buoyancy along the length of the ship, and

(*b*) the wave bending moment, which arises from the differences in buoyancy distribution as between the still water and wave surfaces, then the longitudinal strength problem becomes amenable to a rational treatment, if dynamic effects are neglected.

Shipbuilders are accustomed to the idea of designing for the minimum power to achieve a specified speed and are prepared to take considerable pains to achieve it, notably by tank tests. But the idea of designing for minimum still-water longitudinal bending moment is still comparatively novel. The calculations are neither difficult nor lengthy but they can be most enlightening. Low still-water bending moments pay good dividends to both builder and owner.

The wave bending moment is governed by the shape of the hull. The still-water bending moment is mainly governed by the disposition of weights and can be minimised by skill and ingenuity in the design stage.

The trochoidal wave has long been used in naval architecture, since the sharper crest, as compared with the trough, is presumed to resemble sea waves. For purposes of analysis, however, sinusoidal waves are simpler and easier to use.

To illustrate the calculation of wave bending moments, it is instructive to consider as limiting cases, so far as fullness is concerned, wall-sided ships having

(i) a rectangular waterplane, i.e., a box vessel, and

(ii) a versine waterplane.

(i) In the first example, let L = length of ship, B = breadth, d = still-water draught and let l = length of wave, h = height of wave.

Taking the origin of co-ordinates at amidships and at the still waterline, then for the wave crest amidships, the net volume under wave

$$= 2\int_0^{L/2} \frac{B\,h}{2} \cos\frac{2\pi x}{l}\,dx = \frac{B\,l\,h}{2\pi} \sin\frac{\pi L}{l}$$

so that the parallel sinkage required for equilibrium is

$$\alpha = \frac{l\,h}{2\pi L} \sin\frac{\pi L}{l}.$$

The equation to the load curve is

$$w = \frac{B\,h}{2} \cos\frac{2\pi x}{l} - B\,\alpha.$$

Since shearing force $F = \int w\,dx$ and bending moment $M = \iint w\,dx\;dx$

$$F = \frac{B\,h\,l}{4\pi} \sin\frac{2\pi x}{l} - B\,\alpha\,x$$

and

$$M = -\frac{B\,h\,l^2}{4\pi^2}\left[\frac{l^2}{2L^2}\left(1-\cos\frac{\pi L}{l}\right)+\frac{\pi l}{4L}\sin\frac{\pi L}{l}\right]$$

This gives, for a wave of length equal to the ship length and of height h,

$$M = \frac{1}{35}\,\frac{B\,h\,L^2}{4\pi^2}.$$

The bending moment is a maximum when l = 0·895 L, when it exceeds the value above by about 3 per cent.

(ii) In the second example, by definition, versine $\theta = 1 - \cos\theta$.

Again taking the origin of co-ordinates at midships, with L = length of ship, B = breadth, d = still-water draught, l = length of wave,

$$F = \frac{B}{70}\left[(a-d)\,x + \frac{h}{2}\frac{l}{2\pi}\sin\frac{2\pi x}{l} + \frac{a\,L}{2\pi}\sin\frac{2\pi x}{L} - \frac{L\,d}{2\pi}\sin\frac{2\pi x}{L} + \frac{h}{4}\frac{L\,l}{2\pi(L+l)}\sin\frac{2\pi(L+l)\,x}{L\,l} + \frac{h}{4}\frac{L\,l}{2\pi(l-L)}\sin\frac{2\pi(l-L)\,x}{L\,l}\right]$$

$$M = \frac{B}{70}\left[\frac{x^2}{2}(a-d) - \frac{h}{2}\left(\frac{l}{2\pi}\right)^2\cos\frac{2\pi x}{l} - (a-d)\left(\frac{L}{2\pi}\right)^2\cos\frac{2\pi x}{L} - \frac{h}{4}\left\{\frac{L\,l}{2\pi(L+l)}\right\}^2\cos\frac{2\pi(L+l)\,x}{L\,l} - \frac{h}{4}\left\{\frac{L\,l}{2\pi(l-L)}\right\}^2\cos\frac{2\pi(l-L)}{L\,l}\,x + \frac{h}{2}\left(\frac{l}{2\pi}\right)^2\cos\frac{\pi L}{l} - \frac{L^2}{8}(a-d) - \left(\frac{L}{2\pi}\right)^2(a-d) + \frac{h}{4}\left\{\frac{l\,L}{2\pi}\right\}^2\left\{\frac{1}{(l+L)^2}\cos\frac{(l+L)}{l}\pi + \frac{l}{(l-L)^2}\cos\frac{(l-L)}{l}\pi\right\}\right]$$

$$M_{MAX} = \frac{B}{70}\,\frac{h\,L^2}{8\pi^2}\left[l\left\{\frac{4+\pi^2}{2\pi}\right\}\left\{\frac{l}{L}\sin\frac{\pi L}{l} + \frac{1}{2(L+l)}\sin\frac{\pi(L+l)}{l} + \frac{1}{2(l-L)}\sin\frac{(l-L)}{l}\pi\right\} - \frac{1}{2}\left(\frac{l}{l+L}\right)^2\left\{1-\cos\left(\frac{l+L}{l}\right)\pi\right\} - \frac{1}{2}\left(\frac{l}{l-L}\right)^2\left\{1-\cos\left(\frac{l-L}{l}\right)\pi\right\} - \left(\frac{l}{L}\right)^2\left\{1-\cos\frac{\pi L}{l}\right\}\right].$$

h = height of wave, the volume of displacement in still water

$$= \int_{-L/2}^{+L/2} \frac{B}{2} d\left(1 + \cos \frac{2\pi x}{L}\right) dx = \frac{B L d}{2}$$

so that the block coefficient is 0·5.

In waves of length l, if a is the parallel sinkage required for equilibrium,

$$\frac{L B d}{4} = \frac{B}{2} \int_0^{L/2} \left\{1 + \cos \frac{2\pi x}{L}\right\} \left\{a + \frac{h}{2} \cos \frac{2\pi x}{l}\right\} dx$$

whence

$$d = a + \frac{h}{2\pi} \left\{ \frac{l}{L} \sin \frac{\pi L}{l} + \frac{1}{2(L+1)} \sin \frac{\pi (L+l)}{l} + \frac{l}{2(l-L)} \sin \frac{\pi (l-L)}{l} \right\}.$$

The equation to the load curve is

$$w = \frac{B}{70} \left\{1 + \cos \frac{2\pi x}{L}\right\} \left\{a + \frac{h}{2} \cos \frac{2\pi x}{l} - d\right\}$$

Proceeding as in the previous case, expressions are found for F, M and M_{MAX}, and these are set out across the foot of the previous page.

For a wave of length equal to the ship length, $l = L$, and of height h,

$$M_{MAX} = \frac{1}{35} \frac{B h L^2}{16 \pi^2}$$

which is one-fourth of that for the box vessel.

The bending moment in waves of length l is a maximum when $l = 0{\cdot}64L$ for constant wave height, and then reaches a value 35 per cent higher than the above value of bending moment, i.e., in waves of length $l = L$. The diagrams Figs. 6 and 7 illustrate these results.

From the above simplified analysis, it follows that longitudinal vertical bending moment increases rapidly with block coefficient. This is illustrated in non-dimensional form by the diagram shown in Fig. 7. These results may require modification if the validity of the Smith correction, which takes account of pressure variation within the trochoid, is accepted and if dynamic effects are to be allowed for. The latter, in particular, may well be governed more by loading conditions than by the geometrical form of the hull.

It is believed, however, that the simplified analysis tends towards clarity of thought. With sinusoidal waves, wall-sided vessels have the same bending moments in both hogging and sagging conditions. This is not the case with the trochoidal wave, due to its lack of symmetry in the vertical plane, and this is an additional complication, but the difference amounts to only 6 per cent for the standard L/20 wave.

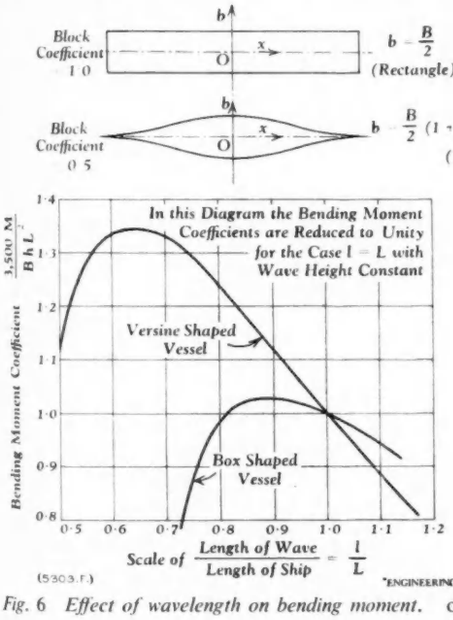

Block Coefficient 1·0
b = B/2
(Rectangle)
Block Coefficient 0·5
b = B/2 (1 + Cos 2πx/L)
(Versine)
In this Diagram the Bending Moment Coefficients are Reduced to Unity for the Case l = L with Wave Height Constant
Versine Shaped Vessel
Box Shaped Vessel
Bending Moment Coefficient 3,500 M/BhL²
Scale of Length of Wave / Length of Ship = l/L
(5303.F.)
"ENGINEERING"

Fig. 6 Effect of wavelength on bending moment.

In general, the calculated maximum stresses in ship hulls are comparatively low, seldom exceeding about 5 tons per sq. in. This does not give ground for complacency, as all hulls must of necessity be punctured by shell doors, hatchways, trunks, etc., and where insufficient care is taken to compensate for such openings, to round the corners, etc., the stress concentration factor may well give local intensities of stress of twice the figures calculated by the standard methods. The problem of stress concentration is vital so far as improvement in hull structures is concerned.

Much excellent work has been done in recent years, notably by the Admiralty Ship Welding Committee, the United States Ship Structures Committee and by the British Shipbuilding Research Association, to determine working stresses in ships by means of strain gauges specially designed for the purpose. There is the persistent difficulty of determining a stress datum, since no zero is readily obtained, but the change of stress in a seaway, due to the passage of waves, can be readily determined by such instruments and figures so obtained are of great value and importance.

TEMPERATURE EFFECTS

One important factor in ship stresses is the effect of temperature change. Strong sunshine on the sides and deck of a ship may well induce temperature stresses as high as those due to loading or to any other causes during the course of operation.

High superstructures, extending over a large proportion of the length, are a characteristic feature of passenger liners and the structural design of these erections has been the subject of much discussion. There are two schools of thought, one considering that the erections should be made an integral part of the hull structure and play their full part in resisting the stresses due to longitudinal bending. The other holds that the erections should be made as light as possible and relieved of stress by means of expansion joints, so that the transmission of stress from hull to superstructure is prevented. There has been a recent renewal of interest in the problem and experimental work in both model and full scale has clarified our physical understanding of the matter and enabled theoretical studies to be made. It is now appreciated that a deep, plated surface, such as a superstructure side or a bridge front, is far too stiff a beam to be compelled to follow the deflection of the ship hull in longitudinal bending. Attempts at such compulsion lead only to such local structural failures as cracking, shearing of rivets, etc., and relief must be obtained either by expansion joints or a radically different design of structure.

SHIP MOTIONS

Until comparatively recent years, it has been customary to assume that the surface of the sea could be represented by a single train of either trochoidal or sinusoidal waves. It has always been appreciated that such a representation was purely hypothetical. Observation suggests that the sea surface is always in a state of complete confusion.

New treatments of the subject* show that behind the apparent confusion there is statistical order, and statistical methods have proved of extraordinary power and utility. Extensive theoretical and experimental studies are now in progress, principally in England, the United States, Germany and Russia. The motions of a ship reflect the complexity of the seaway and in this matter the oceanographer and the naval architect have much to learn from each other.

* Pierson, Neumann and James, "Practical Methods for Observing and Forcasting Ocean Waves by means of Wave Spectra and Statistics." U.S.A. Hydrographic Office Publication No. 603 (1955).

Sea waves are generated by wind. There is always a complex mixture of waves of different periods, since the wind itself is a complex system of gusts. With time, the wave components increase in height independently of each other and the shorter period waves grow in height more rapidly than the longer. The shorter waves reach a limiting steepness and cease to grow while the longer waves continue to grow and begin to predominate. It has been noted that the wave components do not all travel in the same direction, but the directions of most of the components in one single storm lie within ± 30° of each other.

The practical outcome of the above considerations is to represent the sea state by the sum of a large number of sine waves each of which has a particular length, amplitude and phase. The next step is to consider the energy of the wave system and from the continuous energy spectrum all the important statistical properties of the waves can be determined directly.

The action of wind on the surface of the sea is to generate a wave system with a continuous spectrum ranging over a wide band of frequencies, resulting in the apparent confusion which is observed. Now a floating ship has six degrees of freedom:

(*a*) Surge, linear motions in the fore and aft direction.

(*b*) Sway, linear motions in the athwartship direction.

(*c*) Heave, linear motions in the vertical direction.

(*d*) Roll, angular motions about a fore and aft axis.

(*e*) Pitch, angular motions about a horizontal athwartship axis.

(*f*) Yaw, angular motions about a vertical axis.

These motions may, of course, be coupled, and rarely, if ever, occur singly. The motions of heaving, rolling and pitching are oscillatory, since there are hydrostatic forces and moments opposing them. The other motions become oscillatory only in waves.

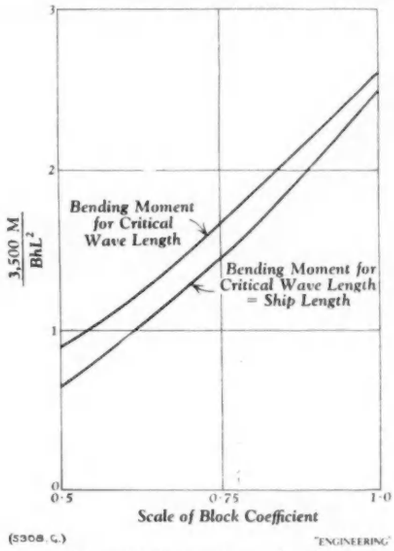


Fig. 7 Effect of fullness on wave bending moment (constant wave height).

It can be shown that in each of the oscillatory motions, the motion is in exact analogy with that of a linear vibrating system with one degree of freedom. In each particular mode, the ship acts as a filter the characteristics of which are defined by the dynamic response curve. This concept serves to explain why rolling, for example, is predominantly in the natural period, owing to the peaked response curve in this mode. Pitching and heaving are more complex motions owing to the relative flatness of the appropriate response curves.

Active steps are taken to damp one motion only, that of rolling. The fitting of bilge keels

Continuing **Design**

is common practice. A still more effective means is the activated fin type of stabiliser, developed in this country by the firms of William Denny and Brothers and Brown Brothers. Such fin stabilisers are becoming standard equipment in liners and cross-Channel vessels. Their effectiveness has been proved in practice and their wide adoption is the most convincing proof of this fact, since normal ship hulls have low damping properties with reference to roll.

One particular type of ship motion, slamming is responsible for much structural damage and the possibility of slamming causes speed to be reduced in waves even in those cases where the decks are not awash and the ship can normally be handled without risk of damage to deck fittings and erections.

It is difficult to give a precise definition of slamming, which is felt by those on board by the sudden change of acceleration, creating the impression that the motion (generally pitching) has been arrested. The acceleration and the motion are largest at the bow and stern and an accelerometer located near the bow shows large readings, and deviation from the normal record, when slamming occurs. Slamming is accompanied by the generation of large pressures on the bottom surfaces under the bow and it is these pressures which cause structural damage. With the sudden building up of these pressures, elastic vibrations of the hull are set in motion. The mechanism of the phenomenon is not precisely understood but damage is usually located on the bottom from about 10 to 25 per cent of the length from the bow.

The importance of slamming lies in its effect on limiting speed. Although power may be available for high speeds in smooth water, the speed in a seaway must be reduced to avoid violent motions and consequent damage. The structural problems of bending and slamming are now being investigated by means of model tests, in several countries.

SHIP VIBRATION

Vibration is always undesirable in a ship, but expecially so in passenger vessels. The causes of vibration are:

(i) unbalanced forces and couples in main machinery, auxiliary machinery and propellers; and

(ii) propeller-excited forces, arising from the non-uniform wake stream.

The vibration itself may be entirely local, occurring in structural parts or members only, or it may be general, arising from the hull vibrating as a girder. The local type is almost impossible to predict in the design stage but can usually be cured in the ship with little expense, often by the addition of local stiffening or pillar support. The general vibration of a hull can be obviated in many cases by careful design, but as a problem it presents formidable difficulties.

The ship girder has many natural frequencies of vibration, arising from bending oscillations in both vertical and horizontal planes, twisting about a longitudinal axis and various combinations of these several modes. The difficulties may be illustrated by reference to the simple case of the vibration of a uniform bar of solid cross-section. The usual equation is

$$\mathrm{E\,I}\frac{\partial^4 y}{\partial x^4}+\frac{\rho\,\mathrm{A}}{g}\frac{\partial^2 y}{\partial t^2}=0$$

where E = Young's modulus,
I = second moment of cross-sectional area,
ρ = density of the material,
A = cross-sectional area, and
g = acceleration due to gravity;
x is measured along the length of the beam and y is the deflection at right-angles thereto.

When rotatory inertia is allowed for, the equation takes the form

$$\mathrm{E\,I}\frac{\partial^4 y}{\partial x^4}-\frac{\mathrm{I}\,\rho}{g}\frac{\partial^4 y}{\partial x^2\,\partial t^2}+\frac{\rho\,\mathrm{A}}{g}\frac{\partial^2 y}{\partial t^2}=0$$

When the effect of shear is included, the equation takes the form

$$\mathrm{E\,I}\frac{\partial^4 y}{\partial x^4}+\frac{\rho\,\mathrm{A}}{g}\frac{\partial^2 y}{\partial t^2}-\frac{\rho\,\mathrm{I}}{g}\left(1+\frac{\mathrm{E}}{\lambda\,\mathrm{C}}\right)\frac{\partial^4 y}{\partial x^2\,\partial t^2}+\frac{\rho^2\,\mathrm{I}}{g^2\,\lambda\,\mathrm{C}}\frac{\partial^4 y}{\partial t^4}=0$$

where
C = rigidity modulus, and
λ = a constant depending upon the cross-sectional shape.

By assuming

$$y=\mathrm{Y}\sin\frac{m\,\pi\,x}{l}\cos p\,t$$

where l = length of bar and p is frequency, we can obtain an equation for the frequency

$$\alpha^2\frac{m^2\,\pi^4}{l^4}-p^2-\frac{m^2\,\pi^2\,k^2}{l^2}\left(1+\frac{\mathrm{E}}{\lambda\,\mathrm{C}}\right)p^2+\frac{k^2\,\rho}{g\,\lambda\,\mathrm{C}}p^4=0$$

where

$$\mathrm{E\,I}\,g/\rho\,\mathrm{A}=\alpha^2 \quad\text{and}\quad \mathrm{I/A}=k.$$

It is then easy to show that the correction for rotatory inertia is comparatively small. But the correction for shear is much larger and becomes predominant as the wave length decreases, i.e., for the higher modes of vibration.

The foregoing shows the difficulties of a reasonably detailed analysis for the case of the simplest possible beam.

In the case of a ship, the hull girder is of non-uniform cross-sectional area and rigidity, the loading varies along the length and the virtual mass effect of the surrounding water must be allowed for. For the fundamental criticals an energy solution can be obtained by Rayleigh's principle, using an assumed curve of amplitude and carrying out the lengthy integrations by graphical means. For the higher modes, recourse must be had to some such eigen-value solution as Inglis' basic functions. Here, again, considerable labour is involved. Many shipbuilders regard the labour as prohibitive, but with modern calculating machines and well-planned computing schemes the work need not be excessive.

In practice, the naval architect appreciates that the r.p.m. of the propeller shafts must never synchronise with a fundamental critical, so he is generally content to estimate the two-node vertical critical with some care. Using ratios derived from experience, he then approximates to the higher frequencies in vertical vibration, and similarly for the frequencies of horizontal vibration. This process is reasonably sound when the vessel being designed does not differ appreciably from a vessel already built for which full information regarding criticals is available. In any circumstances it can give only rough approximations.

Thanks to the work of many investigators, a large amount of vibration data obtained from tests in ships is available. This store of information is continually increasing, but there are still gaps in our knowledge which remain to be filled, notably the effect of superstructures and erections in large passenger vessels.

SHIP DESIGN

We may conclude with some reflections on ship design, and the remarks of Mr. H. L. Cox, made in application to structural design, are entirely apposite. "Design is, after all, an art, and the art of design may be defined as the attempt to achieve a precise object only vaguely known, by the application of strict rules only imperfectly understood."

The naval architect is required to prepare a design for a vessel which must carry a certain weight of cargo and/or passengers at a specified speed, either on trial or in service, for a specific trade. The latter is important, for high-density cargoes require little cubic capacity in the holds while the reverse holds true for low-density cargoes such as grain. If we define deadweight as weight of cargo plus fuel and consumable stores, the designer must choose such dimensions that the displacement is equal to the sum of the deadweight and the lightweight, the latter being equal to the weight of hull including machinery and equipment. The fineness of the hull must be appropriate to the speed and the draught is governed by Freeboard Rules, which thus govern the depth.

Having selected tentative values of length, breadth, depth, draught and displacement, the designer has to achieve a weight balance. He must also secure a moment balance, since centres of gravity in both longitudinal and vertical positions must be such as to provide satisfactory trim and stability. Simultaneously he must estimate the shaft horsepower required for the specified speed, and this power necessarily governs the weight of machinery. The strength of the hull must be adequate for the service but the detailed scantlings can be obtained from the Rules of the Classification Society, although these scantlings govern the weight of steel.

The design should give a vessel of good sea-kindly qualities (however difficult it may be to define these) to comply with the many and varied requirements of the Ministry of Transport, have good steering qualities, be free from troublesome vibration, have the minimum net register tonnage and have a good appearance.

If the vessel is to carry passengers a certain standard of bulkhead subdivision is necessary, with adequate stability under various conditions when the hull has suffered bilging through collision or other accident.

Clearly the achievement of a satisfactory design is a task of some difficulty, wherein the art of compromise plays a considerable part. It has been said that the naval architect must be a master of approximations and this is especially true in design. If the design resembles closely a vessel already built, for which full information is available, the designer makes good use of differential methods, that is, by computing the effects of the differences between the type ship and the design. If no such type is available, he must proceed by a method of coefficients based upon experience, then gradually refine his approximations and when sufficient progress has been made, check his figures by a considerable amount of laborious calculation.

The methods by which naval architects design ships are many and devious. Naturally they are governed by the information available in the particular establishment where the design is being prepared and much depends upon the skill and experience of the designer. It is odd that naval architects are so reluctant to discuss their methods, for papers on design are rarely presented to the technical institutions. The student is left to learn by experience and there are no comprehensive text-books to which he can be referred.

The advantages of pooling information are obvious, and doubtless, in time, some co-operation in design methods and information may be fostered by some such body as the British Shipbuilding Research Association.

The author records his thanks to the Council and Director of Research of the British Shipbuilding Research Association for permission to reproduce Figs. 6 and 7.

LOW CURRENT RELAY

The type R.E. electronic relay made by Londex Limited, Anerley Works, 207 Anerley Road, London, S.E.20, requires a trigger current of only 0·03 mA for operation; the maximum trigger current that can flow is only 0·1 mA. Switching currents up to 4 A at 250 V a.c. or 2 A at 440 V a.c. can be handled.

A single-phase a.c. supply is used to generate the trigger current through an isolating transformer and a cold-cathode relay. External resistance can be as much as 2 megohm. Two versions are now available: one in which the electronic relay is energised when the trigger circuit is closed and one in which it is de-energised. In each case an indicator is illuminated when the relay is de-energised.

Marketing

PUBLICITY FOR EXPORTS

The Government are taking a hand in the promotion of exports by making more widely known the services provided to assist industry in overseas markets. The Central Office of Information have published a series of eight leaflets—attractively produced and most readable—each giving an outline of an existing Government service at the disposal of exporters. To be effective, the Central Office of Information point out that their industrial publicity must enlist the active co-operation of individual firms. The purpose of these leaflets is to strengthen that co-operation. An earlier issue of leaflets drew much favourable comment and resulted in improved liaison between manufacturers concerned with overseas trade and the COI. Some 7,000 sets of the revised leaflets are being distributed to industrial concerns throughout the United Kingdom.

The first leaflet, *Overseas Publicity for Export Promotion*, has for its theme that " the battle for exports is the battle for our standard of living." It sets out the functions of the Overseas Information Services—which go far beyond the provision of mere information. Their newly defined purpose is " to foster abroad the highest opinion of British products and create the right climate in which to sell them." The Federation of British Industries' booklet *Telling Industry's Story Overseas* is quoted on the need for publicity: " It is not enough to-day to make good products; their excellence must also be made widely known," and on the growth of overseas competition in this field: " Our competitors are taking vigorous measures to publicise their industrial products and achievements; we must compete with them in this form of export promotion as we do in any other." The FBI booklet shows how the Central Office of Information and its partners—the BBC and the British Council—with Government support, are " vigorously paving the way for British exports." The leaflet goes on to outline the COI's methods and continues by pointing out that the effectiveness of its industrial publicity " must depend on the amount and quality of the information it is able to gather."

Subsequent leaflets give details of specific services, how each operates, its function, an assessment of its effectiveness and an indication of the part industry can play in making the services more effective. Leaflet No. 2 surveys the many aspects of the Overseas Press Services which are most extensive in their coverage of industrial news and world-wide. Inter alia, a daily programme of industrial news of about 2,500 words is sent by air mail, dealing with Britain's industrial and commercial achievements. The more important topical items are extracted and included in the daily wireless transmissions. Some 2,000 feature articles on British industry are sent in a year. All this and a great deal besides goes out to British information officers in most overseas territories. The quality and appropriateness of the information depends on the care taken by firms in supplying it. Photographs, films and publications (books, pamphlets, magazines and posters) are each the subject of a separate leaflet.

The leaflets will make a most useful contribution to the promotion of mutual understanding between industry and the Government's overseas services and should result in much improved overseas publicity for British industry.

Australian Market for Machinery

Australia is increasingly becoming a market for the more advanced products of the engineering industry. The growth of television has led to the placing of new contracts (awarded to Marconi's Wireless Telegraph Company) for the supply and installation of three new national television transmission stations and studio equipment.

Each of the three stations will be equipped with two Marconi 10 kW television transmitters Type BD371, two 2 kW sound transmitters Type BD325C, a control desk, programme input equipment (vision and sound) and extensive monitoring facilities and spares. The aerial system will consist of a split 8-stack array. All stations—Brisbane (Mirrimbul), Adelaide (Mt. Lofty), Perth (Bickley) and Hobart—will have studios equipped by the same company.

Australian imports of office machinery are also increasing rapidly. The Office Appliance and Business Equipment Trades Association announced that in the first seven months of this year Australia purchased nearly 50 per cent more from British manufacturers of office machinery than she did in the corresponding period of 1957. The industry's exports to the end of July totalled £11·63 million (c.f. 1957: £11·52 million) of which Australia has taken £2·53 million compared to £1·72 million in January to July last year. Such an increase is against the general trend of Australian imports of engineering products and is a good illustration of the export value of the more advanced products, with a high skill content.

Parking Meters Gain Ground

The drive against the commuter is becoming world-wide and in a few years there is unlikely to be much space in which a car can stand without charge. Venners' Electronics Limited are doing very well therefore in export markets where the parking meter has proved to be " one of the best sellers of the fast expanding British time-keeping industry." Switzerland, of all countries, is using some 1,680 British-made parking meters which are operated by a British-made clockwork mechanism. Venners not unnaturally take this as " a proof of their product's superiority to those of competitors from other countries." Export orders so far total 16,000 mainly to Australia (6,750 meters) and New Zealand (4,339).

Not satisfied with this success at the motorist's expense, Venners have developed a " speedmeter" which enables traffic officers " to determine immediately after a car has gone by, whether the driver is exceeding the speed limit or if he is on the right side of the law." The unit is portable and is being used experimentally in this country and overseas.

Selling Electricity by Films

The North Western Electricity Board have set a precedent in the electricity supply industry by producing themselves a 16 mm colour film entitled " The First Ten Years." The object is to put across to the public in the Board's area the considerable improvement which has taken place in electricity generating and distribution. The film illustrates the organisation behind the supply of electricity in an area " stretching from the the Scottish border to Buxton and from the Pennines to the sea," both before and after nationalisation.

The viewer is taken into the testing laboratories, and given a good insight into the Board's breakdown service—the whole area is covered by wireless-equipped vans controlled from 14 broadcasting stations—and of routine maintenance measures. The progress made in the electrification of rural areas is shown, including the methods used by the Board in their attempts to preserve the beauty of the countryside. The pioneer work done by the Board in electrical methods applied to agriculture and horticulture are illustrated. Another feature is an insight into the Board's offices, showing what is being done to simplify administrative procedure including the introduction of standard billing and the steps being taken to standardise tariffs. This is a good example of the use which can be made of films in fostering understanding on the public's part.

Economics in Business

A paper given to the British Association for the Advancement of Science by Ronald Brech, economic adviser to the Unilever Group, dealt with the ways in which economics can make their contribution to the efficiency of business operations. Mr. Brech attempted to close the gap which he said had grown in recent years between economics and business. One of the causes for the gap was the businessman's tendency to turn more and more towards accounting, and therefore to historical data as a background against which to plot the course of his business. The economist, on his side, had sought refuge in the higher realms of political economy.

Mr. Brech indicated three particular fields where economics can be of direct help. The first might be termed the *economic radar system* which can forewarn the businessman about changes in the economic climate both as regards countries and commodities. The second field is as a *tool of management*—the use of economic principles as the basis for management information and statistical techniques as a means of processing the measured information, so as to help businessmen to take the right decisions and subsequently to check the correctness to those decisions.

The third field covers the long-term outlook—*business strategy*—the assessment of the economic future of those industries in which the firm is interested and those countries in which the firm has invested (either fixed assets or goodwill) and the relative position of the firm within its industry or industries.

Flight to Moscow

A service " neatly tailored to meet the demands of the business traveller " who wishes to go to Moscow has been opened by KLM Royal Dutch Airlines. The announcement points out that " there's big business to be done soon in the USSR " and that this will go to " companies who are prepared to go and get it." The service will be reciprocal to that operated with TU-104 jet aircraft by Aeroflot. KLM will initially use Douglas DC-6B aircraft but will doubtless switch to jets when these become available.

The visit to English Electric's Liverpool and Netherton works of a party of 25 Russian engineers is evidence of the need for increased air transport facilities between east and west. The company have many associations with Russia and have supplied both generation and transmission equipment. Much more of this type of contact is inevitable and KLM's venture could well prove to be yet another example of the Dutch company's commercial acumen.

Small Cars from the Big Three

Rumours persist that all three big United States car manufacturers will be in a position to build a small car late next year. Both General Motors and Ford have European subsidiaries whose cars are being sold in the United States. Chrysler's recent large investment in the French company Simca (they took over Ford's 15 per cent holding and Fiat's 10 per cent) places them also in a good position.

Mr. L. L. Colbert, president of Chrysler, forecasts that the United States would import 400,000 foreign cars in 1959. This may be sufficient to decide the Big Three to go forward with their plans to produce locally though even that level of imports may not justify the kind of expensive tooling United States manufacturers usually associate with car production.

Book Reviews

INTERPRETING FOR COMPUTERS

Modern Computing Methods. Notes on Applied Science No. 16. National Physical Laboratory, Department of Scientific and Industrial Research. *Her Majesty's Stationery Office, York House, Kingsway, London, W.C.2.* (10*s.* 6*d.*)

It is fairly certain that more numerical computing is being carried on at the present time than ever before. Modern industry and scientific research provide many problems to which computation is an appropriate, and often the only, solution. In design work there is a tendency to avoid expensive experiments by using computation instead. Where experiments cannot be dispensed with they may be planned by a computational procedure or their results may be analysed by computation. Physical systems can usually be reduced, more or less approximately, to a mathematical problem. The mathematical problem may be attacked by likening it to another physical system which has advantages over the original one in cheapness, speed or flexibility. This is the technique of analogue computers and simulators. A less direct approach to the original physical problem, but often a more accurate and effective one is to attempt an approximate numerical solution of the mathematical problem. This is the technique of digital computation. The computers of the two kinds corresponding to these approaches which are now being rapidly developed in speed and size, were first made possible during the second World War by advances in electronic engineering.

It is instructive to compare the spectacular increase in the use and capabilities of computing equipment with the progress in the subject of computing methods. This progress has consisted of the invention of a few new methods and much theoretical and practical investigation of the suitability of existing methods when used on the large scale permitted by modern computing machinery. The literature is extensive, and substantial books on the subject are not lacking. A recent small volume *Modern Computing Methods* from Her Majesty's Stationery Office is likely to prove particularly useful.

This book, which is of a practical nature, has been compiled from notes of a course of lectures given by members of the Mathematics Division of the National Physical Laboratory on computers for electrical engineering problems. In the space of a hundred pages it covers most of the common numerical problems and techniques for solving them. There are chapters on linear equations and matrix calculations, polynomial equations, ordinary and partial differential equations, relaxation methods and computation of mathematical functions. The amount of mathematical knowledge required does not exceed that likely to be possessed by anyone capable of putting his problem into a mathematical form. In fact, some mathematical background is provided, particularly for matrices. Space is found for some worked examples. There are discussions of the suitability of various computing methods for the different kinds of computing equipment available. Two appendices describe the DEUCE electronic digital computer and the mechanical differential analyser operated at the NPL. No index is provided, though this hardly matters in a small book. The usefulness of the book is enhanced by a good bibliography of 128 items, covering important work done up to 1957.

As a convenient summary of modern computing methods this book can be recommended to the beginner in computing and to the man who has occasionally to turn aside from his usual work to solve a numerical problem. It is clearly printed, and at half a guinea is better value for money than can usually be had at the present time.

RADIATION REFERENCE

Nuclear Radiation Detection. By WILLIAM J. PRICE. *McGraw-Hill Book Company Incorporated, 330 West 42nd Street, New York 36, N.Y., U.S.A.* (8·75 dol); and *McGraw-Hill Publishing Company Limited, 95 Farringdon Street, London, E.C.4.* (70*s.*)

The title of the book is very apt as it is a clear and well presented survey of methods of nuclear radiation detection. It will be useful to the higher student or graduate physicist and most valuable reference book to many nuclear engineers or engineers dealing with radiation health instruments. The book is readable and well illustrated. It covers the properties of atomic radiations and surveys well nigh all kinds of radiation detection methods. Most types of detection equipment are examined in detail, from the more simple types of dosimeters and integrating ion chambers through to the more advanced scintillating counters and fission chambers.

In all chapters the theoretical principles are clearly stated and there is adequate mathematical treatment to show the form of the variables; there are also curves and diagrams clarifying the treatment. Examples are worked out and the reader is left with knowledge of the magnitude of an important variable, and his feet are, so to speak, kept on the ground.

The final chapter deals with electronics for radiation detection and provides a good survey of the principles involved in pulse shaping, discriminating and counting, although it is disappointing in so much as no mention is made of some new techniques such as the use of ferrite cores and transistors for scaling and general pulse work. The book is sufficiently well indexed to rank as a reference work and is generously supplied with references, although, as would be expected, most of these are of United States work.

THE NATION'S HANDWRITING

Handwriting: A National Survey. By REGINALD PIGGOTT. *George Allen and Unwin Limited, Ruskin House, 40 Museum Street, London, W.C.1.* (25*s.*)

A "national survey" of handwriting was conducted during 1956-1957 and the results, with illustrations, are this book. The author obtained over 25,000 specimens of people's handwriting. He analyses them by occupation, style of handwriting, types of pen, and legibility. "Engineers of all trades, carpenters and joiners, etc."—65·8 per cent of them employ Civil Service longhand. This figure may be compared with 72·8 per cent for "heavy manual workers of all grades, etc.," and 44·5 per cent for "scientists, research workers, etc." The arbitrary bracketing of carpenters and joiners with "engineers of all trades," while having a separate category of "heavy manual workers of all grades, labourers, dockers, miners, semi- and non-skilled factory operators, etc.," raises doubts about the significance of the percentages which the author has calculated. The model alphabet proposed by the author might be suitable for quick, clean, and legible lettering on engineering drawings.

On the Shelf

By Frank H. Smith

For those who like wading through booksellers' catalogues in the hope of finding something choice and rare, I would suggest that of Frank Hammond of 129 Steelhouse Lane, Birmingham 4. His latest (No. 114) has, for instance, the first English book on clocks and watches (1675) at £85; Markham's "Masterpiece containing all knowledge belonging to the Smith, Farrier or Horse-Leach touching the curing all diseases in Horses" (1734) at £10 or the works of that old salt John Rudolph Glauber for £85. That last seems a high price for a dose of Glauber.

Chapman and Hall are worried lest my reference (p. 823, 27 June, '58) to their Trade Reference List be taken as meaning that that is all they issue. Actually, of course, they are among the most prolific producers of leaflets on individual books as well as a 300-odd page comprehensive scientific and technical catalogue. I can't help feeling that I have mentioned this before, pointing out at the same time that Chapman and Hall also "do" Reinhold and John Wiley books. Chemists may like to know that C and H have a tract listing new books on their subject from the three houses mentioned. Librarians generally should get the duplicated lists giving their tentative programme for the third quarter of the year.

I wonder why semiconductors always call to mind men standing on the platforms of half-buses? Or, of course, half-Sargents conducting half-orchestras.

A journal that always puts me in mind of the old Nineteenth Century productions (the pages even come in uncut condition) is *Archive for Rational Mechanics and Analysis* published by Springer of Berlin and edited by C. Truesdell of the University of Wisconsin. The editorial board is an international collection of 29. The fourth number of Volume I has a paper "Exact Theory of Stress and Strain in Rods and Shells," with 28 references ranging from 1771 to 1954.

British European Airways now produce a small leaflet called *Approach*. A four-page affair it is addressed to "our friends in industry and commerce" and the first (at least I think it is the first) reviews the opening of Gatwick, the provision of certain new first class services (that's where the friends of BEA are, no doubt), re-routing on Eastern Mediterranean and Persian Gulf services, relations with shipping companies, figures for 1957-58 and cargo by air. I once had the impression—I do not know where I got it—that steamship companies lived on cargo and lost slightly on passengers. This may be quite wrong, of course, but if it is not it may account for the apparent inability of some, at any rate, of the airline companies to make real money and go on making it. After all, a packing case does not care two hoots about the thickness of its sandwich or what is the vintage of its champagne.

McGraw-Hill are handling the Russian-English, English-Russian Electronics Dictionary. It will be ready in August at 62*s.* When I say "the" I merely repeat the press handout. I don't know which. They don't tell me.

Micro Methods Limited, East Ardsley, Wakefield, Yorkshire, will forward (if you ask them) particulars of a new inexpensive microfilm and fiche reader called the Lexicon. It costs £44 and (so they say) is very versatile.

In the very first issue of this column on the 29th March 1957 I mentioned a new service recently launched under the title *Index of Technical Articles*. This was a periodical listing titles of articles appearing in technical journals and at the time I wondered whether a simple list of titles served a useful purpose. A letter has now been sent by the publishers to those editors who gave their journals to this service saying that IOTA is to suspend publication "for the time being".

Metals and Materials

MATERIALS DETONATING IN LIQUID OXYGEN

Although the use of liquid oxygen as an oxidant for various fuels used in liquid rocket propellent systems is not new, it is only in comparatively recent years that it has been observed that some organic materials, when they came into intimate contact with liquid oxygen, became prone to detonation if subjected to certain impact energies. The cause of this dangerous behaviour is generally considered to be due to the formation of unstable organo-peroxide compounds which, when impacted, explode with the release of high levels of energy. For example, when liquid oxygen was accidentally spilled on asphalt and inadvertently stepped on, the asphalt would often explode. Leather gaskets, which had been immersed in liquid oxygen, also detonated with disastrous effects when subjected to surge impact.

Fig. 1 (left) Explosion of a grease after delivery of impact energy of about 70 ft-lb in the presence of liquid oxygen.

Fig. 2 (right) A large number of materials were investigated in the guillotine impact tester, in which a steel hammer on a falling weight hits a striker resting on the sample.

This phenomenon is of some concern to manufacturers of rocket engines and rocket propelled aircraft, as well as their material suppliers, and has prompted the Martin Company, Baltimore 3, Maryland, USA, to investigate the impact behaviour of several lubricants and other organic materials which might possibly be used in liquid oxygen systems. A report of the investigation by D. E. Clippinger and G. J. Morris of the Martin Company's materials and design support department, classifies a number of materials according to their impact sensitivity under these conditions. It was found that the materials which were susceptible fell into the following categories: (*a*) synthetic elastomers and thiokols (*b*) cellulose bond papers; (*c*) silicone and silicate based oils and greases, (*d*) thermo-plastics such as Nylons and phenolics, except pure uncontaminated Teflon; (*e*) thermo-setting resins (phenolics, silicones, epoxies, etc.); (*f*) petroleum based oils and greases. It was noted that no spontaneous reaction occurred when any material was subjected to liquid oxygen. Several materials which had been immersed in liquid oxygen and withdrawn for the impact test while the oxygen was vaporising were found to detonate more violently than when in contact with liquid oxygen. It was also observed that impact sensitivity was related to the thickness of the test piece; thin samples detonating when thicker samples of the same material would not, probably due to the shock absorbing properties of the thicker samples. First impact of some samples would frequently reduce them to a thin, dense layer, which exposed more previously unoxidised material and often resulted in a detonation if the sample was topped with liquid oxygen and re-impacted. The detonations were very audible in all cases; those of lower magnitude were similar to the sharp crack of a 0·22 calibre shell; while those of greater magnitude were similar to the sound of a 0·50 calibre shell. The latter type of explosion was obtained with most petroleum products and a typical detonation for a grease is shown in Fig. 1.

IMPACT TESTING

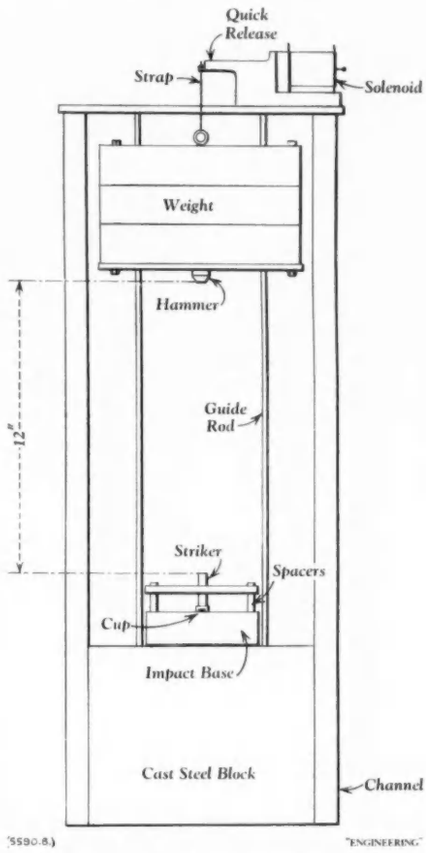
The method of test adopted was based on the recommendations of the LOX Lubricants Standards Committee which met during 1957 at the Ramo-Woolridge Corporation, California, to develop an interim specification for a suitable anti-seize and sealing thread lubricant for use in liquid oxygen systems. This followed the failure of what had been previously considered to be an insensitive thread compound, resulting in the destruction of a rocket engine on a test stand.

Details of the test equipment are shown in Fig. 2. It consisted of a guillotine impact tester using a 71·75 lb weight falling through a distance of 1 ft. A stainless steel hammer mounted on the weight transmitted the impact force to a striker resting on a sample of the material being tested in an aluminium sample cup. The weight was dropped by a quick release mechanism actuated by a solenoid.

The tests were conducted outside a blockhouse on a concrete slab under a partially protective roof. Personnel conducting the test evacuated to the inside of the blockhouse before impacting a sample. A closed circuit television system allowed them to view the impact, and motion pictures were taken of the impact at speeds up to $\frac{1}{128}$ of a second. The temperature ranged from 50° F to 20° F; relative humidity was usually over 70 per cent. Weather conditions ranged from clear to snow and rain, but did not appear to affect the test results.

Materials to be tested were cut to size, approximately 0·5 in square, 0·05 in thick. After cutting they were cleaned and placed in the sample cups. The cup was then filled with liquid oxygen and placed in position in the test equipment. Additions of liquid oxygen were made to the sample cup until boiling ceased. At this point, a clean, precooled striker pin was placed in the cup, resting on the sample. The sample was then impacted. After each impact the striker pin was re-cleaned for subsequent testing.

Results of the impact tests on many common materials have been tabulated and three main categories drawn up: materials acceptable for use in liquid oxygen systems and areas subject to liquid oxygen spillage; materials acceptable for limited use in areas of liquid oxygen spillage; materials rejected for use in liquid oxygen systems or areas of liquid oxygen spillage. Over 100 materials are tabulated, with details of numbers of samples tested and numbers of detonations. In the statistical evaluation of the results, Martin-Baltimore took one detonation in 40 (instead of one in 60 as recommended by the LOX Lubricants Standards Committee), and one in 20 as a basis for acceptance.



MORE OXYGEN USED IN INDIAN STEELWORKS

An expansion programme, which will mean an output of 2 million tons of ingots per year, is now being completed at the Tisco works of the Tata Iron and Steel Company in Jamshedpur, India.

Indian Oxygen Limited is planning to increase both oxygen and acetylene capacity locally to meet the heavier demands which are expected from the steelworks and associated industries in Jamshedpur. Oxygen is at present being used for both cutting and descaling operations in the Tisco works and a programme of process oxygen trials has also been initiated. In addition, oxygen is used in the firm's scrap-recovery process. Another application of oxygen by Tisco is as LOX (Liquid Oxygen Explosives) at their iron ore mines. This process is now also being applied to deep-hole blasting because of the economies which result in comparison with the use of conventional explosives. Altogether, this company's annual consumption of oxygen has increased tenfold since 1935.

Continuing **Metals and Materials**

FLUXES FOR SUBMERGED ARC WELDING

A new group of powder fluxes for submerged arc welding, marketed under the generic name "Muraflux," is announced by Murex Welding Processes Limited, Waltham Cross, Hertfordshire. "Muraflex A," the first of the new fluxes, has been developed as a high-quality general-purpose flux for submerged arc welding of mild steel. It can be used on either a.c. or d.c. supplies, with welding currents up to 900 A, and on any machine suitable for submerged arc welding. The flux is suitable for single-pass or multi-pass welding of various joints as well as plug welds and the building up of worn mild steel parts. Good penetration can be obtained, and unused flux can be used again.

Muraflux A can be used with a normal mild steel filler wire or with a wire containing approximately 2 per cent manganese; both types of wire are available from Murex. When used with Murex wire Muraflex produces welds of high radiographic standard, and can be used for Class 1 work. It has been approved by Lloyd's Register of Shipping and by the Ministry of Transport.

FIRE TEST OF ASBESTOS SHIPS' BOARD

"Turnall" asbestos ships' board, manufactured by Turners Asbestos Cement Company Limited, Trafford Park, Manchester, was recently subjected to an official fire test at the Fire Research Station, Boreham Wood, Hertfordshire. The test was to determine the suitability of the new lightweight board to meet the specifications of "B" class fire retarding divisions.

The test successfully complied with the requirements of insulation and integrity for non-combustible "B" class bulkheads.

The development of this lighter-weight board is another step towards meeting shipbuilders' demands for materials which are lighter in weight and possess a degree of structural strength. The suitability of this low density board for insulating steel and aluminium class "A" fire resisting divisions is also being investigated.

Engineering at Home

FROM THE WOOD

The study of wood bending is among the items of research described in *Forest Products Research* 1957, published for the Department of Scientific and Industrial Research by HM Stationery Office. In particular, a method was evolved at the Forest Products Research Laboratory, Princes Risborough, Aylesbury, Buckinghamshire, for producing hockey sticks with a sharp radius of curvature. Such hockey sticks have become popular in recent years and many made of Indian mulberry have been imported from Pakistan. But the bending properties of home-grown ash have not permitted British manufacturers to produce bends of small radius economically. The method evolved by the laboratory greatly reduces the losses occasioned by making such bends in ash. It consists essentially of producing each bend in two separate halves, the halves then being glued together with a waterproof resin glue. The process has been demonstrated to manufacturers, and playing trials are being made with some of the sticks.

Another investigation carried out by the laboratory concerns the effect of load reversal on strength. Oars, ladders, and scaffold planks can encounter reversals in the direction of loading, any one surface being periodically in tension or compression. Excessive compression stress can result in the buckling of wood fibres and the formation of compression creases; the presence of these may well cause an unsuspected weakening of the timber. Tests on small beams of noble fir, Sitka spruce, and Douglas fir have shown that under impact load the presence of compression creases in the tension or convex region severely reduces strength. Under gradually applied loads, however, compression creases, whether present in the tension or compression regions of a beam, had no significant effect on strength. Tests at intermediate rates of loading are planned.

The sawing machine at the laboratory has been used to investigate a complaint by the Forestry Commission that an appreciable variation occurred in the service life of bow saws having a series of two cross-cut and one raker teeth with hardened tips. Both new saws and saws that had been rejected as unsuitable for further use were examined.

No defect in the sharpening of new saws was readily discernible to the unaided eye but examination with a microscope revealed that the tips of the cross-cut teeth were often fractured and broken off. It was found possible to relate the extent and severity of this damage to the performance of the saw. The number of strokes required by the bow saws to cut a small area of wood varied by about 13 per cent and followed closely an index of bluntness derived from the summation of the width of the damaged tooth points actually engaged with the wood. After some use, the number of strokes required to cut a fixed area of wood varied by about 29 per cent, and an analysis of the results showed that, whereas the increase in the number of strokes was only 11 per cent for the saws with the least damaged teeth, it was over 21 per cent for the saws whose teeth had suffered more extensive damage.

Hand saws have also been studied. As a preliminary to a detailed investigation of factors affecting their performance, a study has been made of the speed and direction of the motion given to such saws in normal use. By means of a regularly flashing light attached to each end of a saw, in line with the teeth, photographic chronocyclegrams of the saw motion have been obtained for a number of operators. This information has been used in the design of a testing machine capable of eliminating the vagaries of hand operation.

Many other aspects of the laboratory's work are included in the report, including work on seasoning, soft rot, and plywood distortion. The report costs 6*s*.

MOWING LARGE LAWNS

The gang mower has long been accepted as a convenient means of cutting large areas of grass. Current practice is showing that small-scale gang mowing is also practical, and a small self-propelled mower, the "Mini-Gang," has recently been introduced by Ransomes Sims and Jefferies Limited, Orwell Works, Ipswich. Both the rear rollers and the wheels of the trailing units, as well as the trailing seat roller, are rubber-treaded. The power unit, the Matador mower, is fitted with side rolls and a five-knife cylinder—also equipped with a rubber treaded landroll, which, state the company, is essential to provide the extra traction necessary for the increased load it has to draw. A front balance bar is added to give greater stability to the whole outfit.

The Mini-Gang mower can cut 1·75 acres in an hour. It has rubber treads on all rollers and wheels.

The use of rubber rolls and wheels in place of plain metal results in a marked reduction in general noise both during operation and, more especially, during transit across harder surfaces such as roads and paths. Also, likelihood of damage to curbs, paths, and grassed areas, or to the machine itself is much reduced. This is an especially valuable feature where the machine is working on grass which is split up by paths.

The 24 in Matador, fitted with a 288 cc JAP four-stroke engine, is augmented by a trailing seat and two Junior J5 trailing units. An overall cutting width of 5 ft is thus obtained. The rate of cutting is about 1·75 acres an hour and the fuel consumption is approximately 1 pint per acre. The price is £263 10*s*.

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